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ENERGETYKA WODNA

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TRMEW

Start the new project with unique innovations of the company WATEC-Hydro

WATEC Hydro

Hydropower – energy for our future

Dear readers and friends of renewable energies. Hydropower is considered to be the cleanest and safest of all energy sources. It offers electricity production in which ecological compatibility speaks for itself without CO_2 emissions and without the consumption of fossil fuels. The longevity of hydropower plants, especially Kaplan turbines, also guarantees long-term environmentally friendly and sustainable power generation.

Insight into the company

WATEC-Hydro, located in southern Germany, manufactures modern vertical-axis Kaplan turbines with runner diameters ranging from 0.4 m to 2.50 m for customers and offers comprehensive and unique know-how for the successful implementation of a wide variety of hydropower projects.

In this context, we offer an extensive portfolio of Kaplan variants:

- KDP Kaplan turbine, double regulated with permanent magnet synchronous generator
- KSDP Kaplan spiral turbine, double regulated with permanently excited synchronous generator and full spiral
- KDD Kaplan turbine, double regulated with direct-coupled V1 generator
- KDR Kaplan turbine, double regulated with belt output
- KDS Kaplan turbine, double regulated as special solution

Comprehensive services

In addition to the new construction of small hydropower plants in the power range from 10 kW to 1,000 kW, WATEC-Hydro has also specialized in the conversion and modernization of hydropower plants. Furthermore, we offer the formwork construction, steel hydraulic engineering as well as the control and regulation technology from one source. If wanted by the customer, Watec Hydro even takes over the measurement of the project completely.

Convincing references

Thanks to the support of the employees, assemblers and external processors, the company has realized over 340 turbine projects throughout Europe in the last 20 years. Since the company WATEC-Hydro serves the complete process from order to construction to logistics, assembly and completion including commissioning, a wide range of customer requirements can be explicitly addressed. An insight into the processes can be taken from our homepage **www.watec-hydro.de**

Business partners wanted

For a market expansion, especially for the Polish area, we are regularly looking for hydropower partners as well as planning offices for a successful cooperation. We are looking forward to your inquiry and to a contact referral to third parties.

If you are interested or have any questions, please contact WATEC-Hydro directly at
info@watec-hydro.de
or **+49(0)8335-989339-0**

www.watec-hydro.de

From The Editorial Office

Without question, the most important event of the past quarter in the small hydropower industry was the release of the latest fourth edition of the highly acclaimed World Small Hydropower Development Report, produced by the United Nations Industrial Development Organization (UNIDO) and the International Centre for Small Hydropower (ICSHP). This report, in my opinion, should be mandatory reading for anyone involved in the hydropower industry, especially decision-makers, developers and representatives of local communities involved in new hydropower projects. The periodic overview of the global hydropower industry by region, including data on existing facilities and ongoing and planned investments, as well as policy frameworks for renewable energy development in each of the countries discussed, is a valuable resource for hydropower companies when planning their development strategies for the upcoming years. No less importantly, the report includes case studies, which are not only an inspiration for industry professionals, but also a reliable source of information for the wider public. This is because they speak in favour of small hydropower plants and show the range of benefits that responsibly built and operated facilities bring to society and the economy. I cordially invite you to read the summary of the report prepared by Danila Podobed and Oxana Lopatina from ICSHP, and as a source of inspiration I cite an extremely important conclusion found in the report's foreword, written by Gerd Müller, UNIDO Director General: "over 60 per cent of global small hydropower potential remains untapped".

Staying in the trend of good practices in small hydropower, I would like to draw your attention to the issue's article, in which Wioleta Smolarczyk and Łukasz Kalina presented the latest implementation carried out by the IOZE hydro team. It included a complete modernisation of the electromechanical part of the Niedalino SHP, including the complete technology of two hydrounits with Kaplan turbines and asynchronous generators, as well as an in-house SCADA system. With this modernisation, a huge technological leap was made and thus a new chapter in the history of the 120th mill was opened.

The recent disaster in India caused by flash floods, which resulted in the Teesta III dam, which was breached and the Teesta V dam severely damaged, should be a source of reflection and motivation for hydrologists responsible for keeping dams in impeccable working order. In this context, it is worth reading the article written by dr Jean-Jacques Fry, Luc Deroo and dr Stéphane Bonelli, in which they presented the new guidelines in France issued by FRCOLD on managing the erosion risks with dams and levees.

Finally, I direct you to an article prepared by Paulina Grądzik, Legislation and Energy Expert at the Lewiatan Confederation, in which she discusses the provisions of the Direct Line Act. The current grid situation in Poland, regulations on grid connections that are not adapted to current market realities, practices of distribution system operators, as well as many other factors delay the development of RES. The solution to these problems was intended to be a connection between the electricity generator and the consumer bypassing the grid infrastructure. However, the provisions of the Act raise many doubts among experts in the industry and lead to the question whether a direct line in Poland will be a real lifesaver for the national grid or a missed opportunity?

Enjoy your reading!

Michał Kubecki
Editor-in-Chief

Partners

Strategic partner

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Photo. Commemorative photo of conference participants
Source: TKZ 2023 archive

XX Technical Dam Control International Conference – report

From the twelfth to the fifteenth of September 2023, the twentieth anniversary edition of the Technical Dam Control International Conference was held in Chorzow. Its theme was the safety of hydraulic structures.

The jubilee edition of the Technical Dam Control Conference was titled "Safety of Hydraulic Structures". The Division of Hydro-engineering and Hydraulics of the Faculty of Building Services, Hydro and Environmental Engineering of the Warsaw University of Technology (WUT) organised the Conference The Silesian Waterworks Company (SWC), Dam Monitoring Center – National Service for Safety of Hydraulic Structures – Institute of Meteorology and Water Management – National Research Institute (IMWM), the Institute for Applied Research (IAR), Warsaw University of Technology Ltd., Polish Committee on Large Dams (POLCOLD) and the Hydrotechnical Structures Division of the Committee on Civil Engineering and Hydroengineering of the Polish Academy of Sciences (CCEH PAS) cooperated with conference Organizer.

The event was held under the patronage of the General Inspector of Construction Supervision, the President of the Polish Chamber of Civil Engineers, the Marshal of Silesian Voivodship, the Chairman of Silesian Waterworks Company and the Dean of the Faculty of Building Services, Hydro and Environmental Engineering, the Warsaw University of Technology.

Two hundred and four participants from 20 countries participated in the Conference, including forty-seven in-person and fifty-six online participants. The chairman of the Organizing Committee, Prof. Jan Winter, welcomed conference guests at the conference opening ceremony. Dorota Cabańska (GICS), Mariusz Dobrzeniecki (PCCE), Zbigniew Faruga (SWC) and Paweł Popielski (WUT) welcomed guests on behalf of the honorary patron. The following representatives of the co-organisers gave welcoming speeches: Maciej Sieinski (IMWM), Piotr Śliwiński (POLCOLD), Zbigniew Kledyński (CCEH PAS) and Apoloniusz Kodura (WUT). The Speakers emphasised the importance of international cooperation and exchanging experiences in water engineering in hydraulic structures' construction and monitoring, as well as scientific and research work conducted in water engineering.

There were four technical sessions organised. The twenty-six papers out of forty-one published were presented during those sessions.

The first session was dedicated to the 140th anniversary of the operation of the Silesian Waterworks Company. Presented papers refer to the history of the Silesian Waterworks Company activity and Goczalkowice Reservoir. Speakers from SWC raised many issues related to the safety of hydraulic structures and maintenance, operation, and modernisation of large water reservoirs in the current law aspects.

Other technical sessions were dedicated to surveying, operating, and maintaining hydraulic structures. The Speakers pointed out the challenges related to the operation of dams and reservoirs in the context of climate change. They discussed the specificity of small dams and hydraulic structures used in agriculture. The papers concentrated on the practical issue of water management and existing hydraulic structure renovation and modernisation. There were also presentations on new technologies in water engineering and modern measurement and monitoring techniques crucial in evaluating the technical state of the earth and concrete hydraulic structures. Participants had the opportunity to learn about examples of new construction materials and modern measuring equipment presented at the exhibition accompanying the Conference.

On the Conference's third day, a technical trip to Goczalkowice Rezervour, administrated by the Silesian Waterworks Company, took place and at the Water Treatment Plant in the Goczalkowice.

Papers submitted to the Conference were published in the following journals: Archives of Civil Engineering, Journal of Water and Land Development, Water, International Water Power and Dam Construction (July 2023), Gospodarka Wodna (9/2023 and 11/2023), Energetyka Wodna (3/2023), Inżynier Budownictwa (7,8/2023 and 9/2023) and a special monograph published by the Institute of Meteorology and Water Management. The XX Technical Dam Control International Conference was co-funded by the state budget, granted by the Polish Minister of Education and Science under the "Excellent Science II – Support for Scientific Conferences" program.

We invite you to follow the Conference's official website: www.tkz.is.pw.edu.pl. We invite you to participate in the next edition of the Conference TKZ'2025.

Prof. Phd Dsc Eng. Jan Winter
Chairmen of the Scientific and Organizing Committees of the XX TKZ 2023 Conference

Phd Eng. Agnieszka Dąbska
Secretary of the XX TKZ 2023 Conference

New RES Directive adopted by the European Parliament

The European Parliament has adopted the new Renewable Energy Directive (RED III). It is intended to significantly speed up the issuing of RES construction permits. In selected locations, it is to take a maximum of 12 months to obtain them.

Source: Pixabay, Sakulich

Works under the new EU Renewable Energy Directive (RED III) are getting closer to being finalised. On 12 September this year, the European Parliament voted in favour of its adoption. 470 Members voted in favour of the new, more ambitious legislation and the acceleration of investment in RES during the plenary session of the Members of the European Parliament, 120 voted against and 40 abstained.

The overarching goal of the RED III Directive is to increase the share of RES in final energy consumption in electricity, heating and transport in the European Union to at least 42.5% by 2030. However, under the directive, EU countries are to aim for 45%. This represents a significant increase in ambition compared to the target enshrined in the 2018 EU RED II Directive. It provides for an increase in the share of RES to 32% by 2030. With the higher target, the EU's green energy sector is to contribute to a new target of reducing greenhouse gas emissions in the EU by at least 55% by 2030 compared to 1990 levels. This target stems from an EU strategy referred to as 'Fit for 55'.

In order to ensure that the share of RES in the EU's energy consumption increases to at least 42.5%, according to the new Directive, EU countries are to explicitly accelerate the issuing of permits necessary to launch new RES investments.

The RED III directive assumes that EU countries will set aside special zones in which the implementation of RES projects will involve simplified procedures regarding environmental assessment. In the zones defined as 'renewables go-to areas', investors are to obtain permits for the construction of wind and photovoltaic power plants in a maximum of 12 months (in the case of maritime zones, a maximum of 24 months has been adopted). Permits for smaller RES installations – up to 150 kW – and repowering projects are to take even less time. EU countries are to designate such zones within 30 months of the RED III directive coming into force.

The RED III Directive aims to reward investments in renewable energy using technologies that are considered innovative. These are to account for at least 5% of new renewable energy capacity. In addition, under the new law, member states are to adopt mechanisms to facilitate cross-border investments in renewable energy.

The implementation of the new Renewable Energy Directive still needs to be approved by member state ministers at the EU Council.

GRAMWZIELONE.PL

Editorial office
gramwzielone.pl

Water shortage prevention programme adopted

The Council of Ministers adopted a resolution on the adoption of the Programme for Counteracting Water Scarcity for 2022–2027 with an Outlook to 2030, submitted by the Minister of Infrastructure. It will increase water retention in Poland. The planned measures will have a positive impact on water management, especially in terms of reducing flood risk and mitigating the effects of drought. The programme will provide for both artificial and natural retention.

Poland, because of its geographical location, has scarce water resources. The problem of water deficit and the associated drought phenomenon has intensified in recent years. Our country is in penultimate place in Europe in terms of water resources. There are approximately 1,600 m³/year per inhabitant in Poland, while in Europe the average is 3 times more. This is why we are taking measures to increase retention", said Deputy Minister of Infrastructure, Government Plenipotentiary for Water Management and Investments in Maritime and Water Management Marek Gróbarczyk.

The programme proposes measures aimed at increasing reservoir, riverbed, forest, agricultural and urban retention. Educational, informational and promotional activities have also been indicated, which concern the strengthening of public awareness of the need to retain and save water.

The programme is expected to increase the volume of water retained, as well as increase the area and improve conditions for water and water-dependent ecosystems. The availability of water resources for agriculture will also be improved. The programme is expected to result in an increase in water retention in Poland from 7.5% (currently) to 15% in 2030.

A total of 727 investments are envisaged, including 94 water retention facilities (reservoirs) and 633 facilities that shape retention (damming, regulating and other structures).

Press office
Ministry of Infrastructure

State Water Holding Polish Waters

Another modern reservoir in the Kłodzko area

Another of the modern polders being built by the Polish Waters in the Kłodzko Land is ready. The Krosnowice dry reservoir on the Duna stream in the Kłodzko municipality will hold nearly 2 million m³ of water and, in cooperation with the other three new flood control facilities, will strengthen the protection of Kłodzko, a town with a population of 25,000, against the threat posed by the sudden water surges typical of the region.

Source: State Water Holding Polish Waters

Photo. Krosnowice reservoir

A key stage in the activities of Polish Waters in the Kłodzko area is in its final phase. The construction of four dry flood control reservoirs in Roztoki, Boboszów, Krosnowice and Szalejów Górne within the Oder and Vistula River Basin Flood Protection Project is nearing completion. The purpose of the polders is to reduce the flood risk in the river valleys on which they are located and indirectly also on the Nysa Kłodzka. The total retention capacity of all four polders is more than 16 million m³ and will directly protect 1,200 local residents. At the last of the facilities under construction in Szalejów, work is expected to be completed in the last quarter of this year. A ceremonial opening of the reservoir was held on 29 September with the participation of representatives of the Polish Parliament, the European Commission, State Water Holding Polish Waters, local government officials and contractors.

The first, completed in 2021, was Roztoki Reservoir, located on the Goworówka stream. Its capacity is 2.7 million m³ and the area of the reservoir at maximum damming reaches 48 ha. The dam of the reservoir is 756 m long. In the summer of 2023, in turn, the Boboszów reservoir on the Nysa Kłodzka was completed and put into operation. Its capacity is 1.4 million m³ and the area of the reservoir at maximum damming is 21 ha.

The Krosnowice reservoir is similar in size to the above-mentioned reservoir. Its capacity is 1.9 million m³. The area of the lagoon at maximum damming is 44 ha, while the length of the dam is 452 m and the maximum damming height is 14 m. The construction lasted from 2018 to 2023 and cost nearly PLN 175 million, including EU funding of more than PLN 43 million under OP Infrastructure and Environment 2014–2020. The construction of the Krosnowice reservoir was carried out in accordance with all environmental requirements. More than 85% of the reservoir's bowl is left in its natural state. The structure of the facility allows the migration of fish, nesting boxes for wagtails and boxes for bats have been hung. In addition, 7,700 coniferous and deciduous trees have been planted. Nearly 8,400 shrubs were planted as restoration of oak-hornbeam and riparian natural habitats.

Mentioned reservoirs, with a facility in Szalejów Górny, will create a modern system to manage the flow of floodwaters. All four polders will intercept and reduce the flood wave. The facilities are fully automated and equipped with a data transmission system with the possibility of local control, from the reservoir management centre in Kotlina Kłodzka, as well as from the Flood Protection Operations Centre of the Regional Water Management Board in Wrocław. The total cost of the project for the tasks covering the construction of all four reservoirs, is over PLN 976 million, including a subsidy of just under PLN 370 million from the European Union under the Cohesion Fund.

The second stage of flood protection for the Kłodzko area is the modernisation of the existing flood protection infrastructure in the largest towns in the region and the elimination of bottlenecks on the Nysa Kłodzka and its tributaries to enable safer passage of flood waves and avoid the threat of flooding.

In the framework of this investment, repair and restoration works will be carried out on selected sections of the Nysa Kłodzka, Biała Lądecka, Morawa, Bystrzyca Dusznicka and Kamienna Potok in the most urbanised towns of the Kłodzko Land. These are Stronie Śląskie, Lądek-Zdrój, Kłodzko, Bystrzyca Kłodzka, Długopole-Zdrój, Międzylesie, Polanica-Zdrój and Szczytna. In each of the localities, the project was consulted and discussed with residents and local authorities as early as 2019, resulting in solutions that increase flood protection and meet the public's expectations. All works will be carried out with minimal interference in the unique natural and architectural values of the region.

In total, in the Kłodzko area, State Water Holding Polish Waters is currently implementing a several-stage flood protection strategy for the area worth PLN 1.2 billion to protect the lives and property of residents and the local infrastructure and cultural heritage.

Press Office
State Water Holding Polish Waters


Photo. Malinówka 2 reservoir

Source: State Water Holding Polish Waters

Work on Krakow's water reservoirs completed

Polish Waters in Krakow has completed work on the Malinówka 1, Malinówka 2 and Serafa 2 reservoirs. The dry flood reservoirs will help improve flood safety in the Serafa valley. The cost of building the three reservoirs is almost PLN 30 million.

Polish Waters Regional Water Management Board (RZGW) in Krakow carried out the project 'Flood protection in the Serafa river valley'. The investment included the construction of three dry flood control reservoirs Malinówka 1 and Malinówka 2 and Serafa 2. The polder system will reduce the flood risk on the Serafa river below Wieliczka, and in particular protect the Stary Bieżanów estate. It is in this area that, due to the shallowing of the riverbed and dense development, flooding and localised inundation of the area is very frequent.

As part of the work, overflow and discharge facilities, side dams, the reservoir head dam and the reservoir bowl were constructed. The current capacity of the three reservoirs and the Bieżanów reservoir is 336,000 m³. The investments are being carried out within the framework of the Flood Protection Project in the Oder and Vistula river basins, with the participation of international financial institutions – the International Bank for Reconstruction and Development, the Council of Europe Development Bank and the state budget.

Press Office
State Water Holding Polish Waters

A letter of intent for the construction of a new water reservoir signed

State Water Holding Polish Waters and the municipality of Galewice in the Łódzkie voivodship have signed a letter of intent concerning the construction of the Okoń retention reservoir.

The aim of the investment is, as informed, to increase the retention capacity and counteract the effects of drought in the Warta water region, especially in the catchment area of the Struga Węglewska river and the Galewice municipality. The facility is to be created by damming up the waters of the Struga Węglewska River through the construction of a dam. A reservoir with a capacity of 800,000 m³ and an area of 37 ha is planned. The valley will be flooded, but no dredging is required. In addition to the head dam that baffles the valley of the Struga Węglewska, overflow and overflow facilities and fish ladders will be built. The stage related to obtaining an environmental decision is currently underway. Bogumił Nowak, director of the Poznań branch of the Polish Waters responsible for the area, emphasised the various functions of the Okoń reservoir: "it is worth pointing out that in addition to this purely retention, anti-drought function, it will also have a flood control significance, but above all, in the case of the river that will be dammed here, the Struga Węglewska, it will also aliment water in times of shortages. During these periods when we actually have very little rainfall, biological life will be able to function within this reservoir all the time,".

Łukasz Madej
inzynieria.com

TRMEW news

Summertime is always very quiet in legislative terms. However, this year has been particularly busy for the Polish government, all because of the elections in October. What important things from the point of view of our industry happened in the last quarter?

In August, President of the Republic of Poland signed an amendment to the RES Act of 17.08.2023 (the so-called UC 99 project) introducing several changes that are relevant for SHPs. First and foremost are the provisions on modernisation, as well as operational support for, among others, SHP installations. However, these solutions will only become effective after they have been notified to the European Commission, and this procedure will take at least another few months. An interesting project that we do not have to wait for is a solution called cable pooling, which means the possibility to combine various RES installations at a single point of connection to the power grid. These installations can use the already concluded connection contract of one of them. This is the seed of an interesting expansion for many generators, but there are issues that need to be clarified. Together with the Lewiatan Confederation, we are working on the clarification and interpretation of the provisions introduced in the Act.

Another interesting solution, this time for energy clusters, is the cluster register. You will certainly remember that our Association is the Leader of the Renewable Energy Cluster Grudziądz – Energy Sustainable Area. Thanks to the new possibilities we can report our cluster to the register of energy clusters kept by the Energy Regulatory Office and take advantage of the opportunities to promote the above activities. We will be discussing these topics with the participants of our RES Cluster. I will certainly share our findings with you.

At the end of September, the Distributed Energy Congress was held, organised by the AGH University of Science and Technology in Krakow, of which our Association was the Substantive Partner. During the conference, a common position of organisations developing distributed energy was developed and signed, the first point of which was to emphasise that "Poland needs stable development of distributed energy, which can and should be one of the main elements of the country's energy transformation". The entire position has been published on our website – I encourage you to read it".

I am referring you to our website not without a reason. Yes! We have a new website and I believe you will like it. We had to make changes because the previous website was technologically outdated and did not serve its purpose.

Finally, I am very happy to announce that the Hydro-Forum TRMEW organised by our Association will take place on 23–24 November. You are cordially invited to it! This is another opportunity to exchange your experiences and insights into our activities. For more details at www.trmew.pl.

Monika Grzybek
Office manager
TRMEW

Calendar

16–18.10.2023 Edinburgh, Scotland	**HYDRO 2023** Organizer – Aqua~Media International	www.hydropower-dams.com/hydro-2023/
19–20.10.2023 Uniejów, Poland	**VIII Smart Development Forum** Organizer – Smart Development Forum	www.irforum.pl/wydarzenie/
24–25.10.2023 Wrocław, Poland	**CITY-WATER-QUALITY OF LIFE CONGRESS** Organizer – Foundation for Public Economy and Administration	https://watercity.com.pl/
25–27.10.2023 Wrocław, Poland	**Polish Hydropower Conference HYDROFORUM 2023** Organizer – Polish Hydropower Association	www.hydroforum.tew.pl
31.10–2.11.2023 Bali, Indonesia	**World Hydropower Congress 2023** Organizer – International Hydropower Association	www.worldhydropowercongress.org
6–9.11.2023 Amsterdam, Netherlands	**Aquatech Amsterdam** Organizer– Rai Amsterdam	https://www.aquatechtrade.com/amsterdam/
7–9.11.2023 Genoa, Italy	**HYDRO 2023 – Hydrographic Conference** Organizator – Triumph Group	https://hydro2023.com/
7–10.11.2023 Rimini, Italy	**ECOMONDO** Organizator – Italian Exhibition Group	https://en.ecomondo.com/
14–16.11.2023 Łódź, Poland	**XXVI Congress WOD-KAN-EKO** Organizer – BMP	www.kierunekwodkan.pl
21–23.11.2023 Lublin, Poland	**Energy Trade Fair ENERGETICS 2023** Organizer – Lublin Fair	https://energetics.targi.lublin.pl/
23–24.11.2023 Woźniki, Poland	**VIII Hydro-Forum TRMEW** Organizer – Polish Association for Small Hydropower Development	www.trmew.pl

From the World

07.07.2023 Porr wins contract to build caverns and tunnel system for Forbach pumped storage plant

Construction company Porr has secured a major contract for the construction of caverns and a tunnel system as part of the conversion of the Rudolf Fettweis Plant (RFW) in Forbach into a pumped storage power plant. EnBW Energie Baden-Württemberg AG, the project's investor, is set to invest approximately €280 million in the conversion, with Porr being awarded Lot 2 "Civil works" worth €98.3 million.

The heritage-protected Forbach run-of-river power plant, dating back to 1914, played a crucial role in electrification in the north of the Black Forest. Its conversion into a pumped storage power plant is expected to significantly improve its efficiency. Previously, water from the Schwarzenbach and Murg dams would flow into an equalization basin and then into the Murg after passing through the turbine wheels. However, the conversion plan includes the construction of an underground sub-basin, serving as an indirect power reservoir, allowing the water to be circulated as desired for electricity generation. The construction is scheduled to commence in autumn 2023 and the new power plant is planned go into operation in 2027.

24.07.2023 Argonne-NREL study highlights Alaska's potential for pumped storage Hydropower

In a significant stride towards renewable energy integration, scientists from Argonne National Laboratory and the National Renewable Energy Laboratory (NREL) have revealed their findings from an exhaustive study identifying potential sites for pumped storage hydropower projects across Alaska.

The study – The Prospects for Pumped Storage Hydropower in Alaska – focused on mapping and geospatial analysis to pinpoint potential locations suitable for pumped storage hydropower development. Scientists identified about 1800 sites in the state.

Alaska, known for its rapid warming and environmental challenges, presents unique energy needs due to its vast size and isolated communities. Unlike many other states, Alaska lacks connection to large interstate energy grids, relying on more than 150 small, standalone systems. To address this, researchers explored the integration of pumped storage hydropower to store excess energy from intermittent renewable sources and provide a stable power supply during periods of scarce wind and solar availability. Using the Argonne Low-Carbon Electricity Analysis Framework (A-LEAF), the scientists created detailed models for power system operations and planning, considering past and present energy transmission trends. They also analyzed the expected overall growth in electricity demand over the next 25 years and took into account the retirement of existing generators as they reach the end of their economic lifetimes.

A key finding from the A-LEAF modeling is that the Railbelt system will require both short- and long-duration energy storage in the future to balance the variability of wind and solar generation and ensure reliability and backup capacity during extended periods.

The study revealed that pumped storage hydropower can provide roughly 10 or more hours of energy storage, making it a promising option for meeting the region's energy needs.

28.07.2023 Gilkes commissions hydropower turbine at water treatment plant in the US

Hydro engineers from Gilkes have recently returned from the US, successfully completing the commissioning of the company's latest hydropower turbine in North America. The installation of the 867 kW Vertical Four Jet Pelton took place at Sherard Water Treatment Plant in Wyoming. The project aims to utilize the existing raw water pressure to power the City of Cheyenne's water treatment facility. The groundwork for this project began two years ago with the construction of a dedicated powerhouse. The turbine operates using water flows from Cheyenne's water supply as it enters the plant. The main purpose of this hydropower system is to provide energy for the treatment plant, which typically consumes 200 to 400 kW. Any surplus power generated will be channeled back to the grid, potentially benefiting the community by contributing clean energy resources.ting the community by contributing clean energy resources.

31.07.2023 Resumption of planning for Pradapunt hydropower plant, Switzerland

The 'Wasserkraft Plessur' project consortium has decided to reinitiate its ambitious plans for the construction of the Pradapunt hydropower plant in Switzerland, a project that holds the potential to supply electricity to approximately 10,000 households in the future. This development marks a significant stride in augmenting Graubünden's hydropower capacity.

The new Pradapunt power plant will use the slope of the Plessur between Litzirüti and Pradapunt to produce 42 GWh of hydropower each year. Among its critical objectives is bridging the existing gap in the power plant cascade on the Plessur and curbing the detrimental discharge fluctuations from the Litzirüti power plant, which have been impacting the local natural environment. The consortium's immediate aim is to submit a revised license application over the course of the upcoming year. However, given the complexity of license and building application procedures, the consortium partners may only be able to make investment and construction decisions by 2027. Subsequently, the actual construction of the power plant is expected to take approximately three years.

From the World

30.08.2023 Green hydrogen production commences at site near Schiffenen Dam

Groupe E has successfully kickstarted the production of green hydrogen at its plant situated near the Schiffenen dam. Currently, the company is in the process of conducting essential tests and making adjustments to prepare for the complete utilization of the facilities. The objective is to have the new site capable of producing approximately 300 tonnes of green hydrogen annually, which will be used to support the decarbonization efforts in the industrial and heavy mobility sectors. Groupe E's milestone achievement brings the first-ever industrial-scale production of green hydrogen molecules to western Switzerland. The recent commissioning of two 1 MW electrolyzers at the site near Schiffenen dam signifies a significant step forward in sustainable energy technology.

The Schiffenen hydrogen power plant project is pioneering in the context of western Switzerland, encompassing the entire hydrogen supply chain within a single location. At the heart of this initiative is the endowment turbine, located near the dam. This turbine operates consistently to maintain water flow for aquatic life and supplies the necessary electricity for water electrolysis, a key process in hydrogen production. Notably, surplus electricity generated, amounting to approximately 8,000 hours annually, is harnessed for this purpose. The produced hydrogen is then compressed, stored in tanks, and readied for road transportation, catering to regional demand.

05.09.2023 Snowy Hydro announces new completion date and cost estimate for Snowy 2.0 Project

Snowy Hydro has unveiled a new completion date of December 2028 and a revised total cost of $12 billion for its flagship project, Snowy 2.0, following an extensive review and reset process.

In a statement, the company said that as of June 2023, $4.3 billion had already been invested in the project, with approximately 80% of these funds contributing to the Australian economy. It also said that first power generation from the project is now slated for the second half of 2027, with a subsequent target date for full commercial operation of all units set for December 2028. One of the key changes included in the reset is a shift from the fixed-price Engineering, Procurement, and Construction (EPC) Contract to an incentivized target cost contract model. This transition is being carried out in collaboration with the Future Generation Joint Venture (FGJV), Snowy Hydro's partner in the project. Additionally, Snowy Hydro is actively resolving all outstanding claims with FGJV. Through the project reset process, Snowy Hydro has successfully enhanced the project's capacity by 10%, resulting in a total dispatchable generation capacity of 2200 MW. Furthermore, Snowy 2.0 will provide energy storage of 350,000 MWh, equivalent to 160 hours of generation at maximum output. The cost revision reflects the cumulative impact of various external factors, including the challenges posed by the COVID-19 pandemic, labor shortages, disruptions in global shipping and supply chains, inflation in construction materials and labor costs, as well as design complexity. Despite these challenges, Snowy 2.0 remains economically viable, with strong market demand expected to support its services well into the future.

26.09.2023 European Commission's Horizon Programme initiates call for hydropower equipment development projects

The European Commission, under the Horizon research Programme, has announced a call for projects focused on the "Development of hydropower equipment for improving techno-economic efficiency and equipment resilience in refurbishment situations". This initiative is aimed at bolstering the sustainability, efficiency, and competitiveness of the hydropower sector, with a specific focus on the European Union as part of the broader #REPowerEU context.

The primary objectives of this call for projects are to enhance the efficiency and resilience of hydropower equipment used in the refurbishment of existing hydropower plants, particularly those that are outdated concerning efficiency, power market integration, climate change adaptation, and environmental sustainability. The project's scope includes the development of novel technologies that can improve the efficiency and economic aspects of existing hydropower installations during refurbishment without the need for significant modifications to the hydraulic systems. Key components of these technologies involve implementing circularity by design, such as low-friction and resistant materials and technical solutions that can minimize wear and tear during future operation modes. The expected outcomes of these projects are multi-faceted, with a focus on:

- Ensuring that the existing hydropower fleet plays a significant role in the future power market by operating as flexible power suppliers.
- Increasing the technology leadership and competitiveness of the European hydropower industry, while also enhancing its potential for technology exports.
- Reducing the costs and improving the efficiency of refurbished hydropower installations.
- Prioritizing the sustainability of refurbished hydropower plants, with a strong emphasis on considerations such as the circular economy, social factors, economic aspects, and environmental impacts. These goals align with the European Green Deal's priorities, which include energy and climate targets and biodiversity preservation.

The call for project proposals will be open until January 16, 2024, at 17:00 Brussels time.

Photo. Lac de Serre-Ponçon reservoir, Southern Alps, France

Source: Authors archive

New guidance in France on managing erosion risks associated with dams and levees

FRCOLD has published recommendations for the stability of gravity dams (2012), spillway safety (2013), embankment dam stability (2015), and stability of arch dams (2018). In 2023, it will publish recommendations on the justification of embankment dams to erosion. These recommendations concern both internal and external erosions, which represent nearly 90% of the causes of dam failure. They apply to three types of structures: dams, side dams or canal embankments and levees.

The guidance distinguishes between recommendations, that are mainly methodological in order to comply with the regulations (situations, mechanisms, loads and general approaches to be followed), good practice that gathers the methods approved by the 26 experts of the working group and finally new approaches, resulting from recent research used by some members without having been validated by all the experts.

The approach of the erosion safety assessment is based on the following features:

- The location and characterization of all potential erosion paths;
- Erosion processes are grouped into 4 internal and 5 external erosion mechanisms;
- The justification process follows 7 steps: 1 – preliminary documentary survey; 2 – potential erosion paths; 3 – Ground models; 4 – loading situations; 5 – Justification of the erosion resistance of the barriers; 6 – Safety assessment along each erosion path; 7 – Synthesis;
- The approach to internal erosion analysis is graded into three levels: 1 – functional analysis; 2 – functional and behavioral analyses; 3 – functional, behavioral and numerical or physical analyses;
- The approach of the external erosion analysis is based on three types of justifications: 1 – absence of solicitation; 2 – solicitation without initiation of erosion; 3 – initiation of erosion without progression towards the breach.

All of these will be re-evaluated after a few years of practice.

The reinforcement of the French regulation in the field of hydraulic safety

In France, there is more than one failure of hydraulic works per year caused by erosion: breaches of navigation canals or flood protection works and failure of small dams for irrigation or water supply purposes. These statistics have reinforced the idea of unifying the procedures for controlling the safety of all the hydraulic structures, whatever their purpose (electricity, navigation, irrigation, drinking water, tourism, and so on) and of forcing the owner to carry out and submit a hazard study ("Etude de Dangers" in French called EDD) to the control authority. These two objectives were the basis for the modification of the law on water and aquatic environments (LEMA) and the launch of the decree "safety of hydraulic works" in 2007 in France. The main contributions of this new law and decree are:

- The Permanent Technical Committee on Dams (CTPB), a group of 8 experts with more than 35 years of experience in charge of checking the safety of any new large project, becomes the Permanent Technical Committee on Dams and Hydraulic Works (CTPBOH).
- Dams are classified in 4 categories according to their height and their impoundment, whatever their destination (class A > class B > class C > non classified).
- In-depth technical visits (VTA), monitoring reports and hazard studies (EDD) for the first two classes (A and B) are mandatory and their periodicity varies according to the classes.
- Events occurring during operation (floods, earthquake, accident, anomalies, and so on) must be declared, breaking the temptation to "not seen, not taken".
- The structures whose purpose is to store water are called dams (the canals are lat-

eral dams) and those whose purpose is to protect against floods are called levees.

The hazard study (EDD) is an opportunity for the project owner to become aware of the risks that his scheme generates for property and people. It details the severity of potential accidents, provides an assessment of the probability of occurrence of these accidents and presents the main measures that have been taken to reduce these risks or that are planned in the short or medium term. The periodicity of hazard studies is currently 10 years for class A dams and 15 years for class B dams.

Subsequently, new laws voted in 2014, 2015 and 2017 focus on levees and entrust the management of aquatic environments and flood prevention (GEMAPI) to the inter-municipalities. The GEMAPI aims to establish the responsibility for the organization of the management, efficiency and safety of flood protection systems in maritime, river and torrential sites and the rapid and effective implementation. This implementation opens many new works.

Verification of the safety of hydraulic installations

The implementation of hazard studies for dams since 2007 and for levees systems, hydraulic facilities for temporary water storage and river, torrential and maritime protection systems and structures since 2013 have prompted the scientific and technical community to work on issues related to flood protection levees. Indeed, the current approaches and in particular the current application of the Eurocodes do not provide sufficient support to improve the safety of hydraulic structures.

The limits of application of the Eurocodes to hydraulic structures

According to Eurocode 0, the limit states define the admissible limits with respect to the safety of people and goods and with respect to the appearance of the structure. Still according to Eurocode 0, the ultimate limit states (ULS) allow the calculation of everything related to the safety of people and/or the safety of the structure. But where are the ULS that allow to calculate the erosion resistance of hydraulic structures? Would they be the hydraulic heave Limit State (HYD) and the buoyancy Limit State (UPL Ultimate) only? No! These two ELU define the admissible limits of the equilibrium of a mass subjected to a hydraulic head loss and caused respectively by inclined hydraulic and vertical gradients (uplift). These states do not guarantee in any way the stability of a grain subjected to the hydrodynamic forces of a flow. In other words, the Eurocodes do not protect hydraulic structures from breaches by erosion. It is therefore not surprising that 85% to 95% of failures are due to water action. This reason alone explains why the Eurocodes are not applied to hydraulic structures.

Suppose we want to apply the concept of limit states to hydraulic structures, what should we do? First of all, it would be necessary to distinguish the concept of general stability applicable to a portion of the structure from the concept of granular stability applicable to the most unstable grain, in order to know the conditions of its detachment (initiation of erosion) and then the conditions of its transport (continuation) through the constrictions of the most permeable zone. To reach this distinction, it is necessary to add to the notion of characteristic value of the mechanical properties of a soil, which gives access to the resistance of any section of the structure, the notion of extreme value of the hydraulic properties (porosity and permeability), a value which conditions the initiation and then the transport of a set of grains one by one. A crucial question then arises: how to have access to an extreme value at a time when the statistical distribution of values is not automatically sought? This dilemma needs to be addressed, as it is still unresolved. Soil investigation offices are used to extracting mechanical property distributions (peak resistance, pressure modulus or limit pressure) from their investigation campaigns, but permeability values are rare, scattered and subject to uncertainties, and the acquisition of time series of springs and water tables is often limited to the monitoring of a few boreholes transformed into piezometers during construction. This disproportion between mechanical and hydraulic data is probably at the origin of many errors and contractual conflicts. The Eurocodes do not provide the data that give meaning to a safety factor threshold or to the various safety margins to be taken on a leakage rate.

The strict definition of the concept of Serviceability Limit State is the following difficulty. The serviceability limit states (SLS) make it possible to check the good functioning and the good aspect of the structure, the comfort of the persons, the durability of the work and the preservation of these components in normal situation. They do not have the task of carrying out these verifications in rare, accidental or extreme situations. However, it is the rare situations of flooding, accidental situations of damage to the waterproofing or loss of drainage and seismic situations that generate the most damage.

In 1993, the French Committee for Dams and Reservoirs (the French national committee involved in the International Commission on Large Dams or CFBR in French) launched a working group on this issue. Facing with feedback that points to a minimum of one annual failure of hydraulic structures and 85 to 95% of dam failures by erosion, it launched a national working group and proposed a European working group in 1993 within the International Commission on Large Dams. It relies on the IREX to develop numerous erosion tests and apply them to the reality of the field within the research ERINOH project (Internal Erosion of Hydraulic Structures). Since 2012, it also relies on the scientific spin-offs of the Technical Committee 213 of the International Association of Soil Mechanics and Foundations. This reflection is now synthesized in new recommendations that are being examined by its Executive Commission and should be published this year.

CFBR recommendations

The assessment and management of risks, vulnerability, resilience of territories and the reliability of existing structures and systems are stimulated by recent changes in regulations. The recommendations of the CFBR, for gravity dams (2012), spillways (2013), embankments dams (2015) and arch dams (2018) allow to unify and improve the practice of studies. The synthesis of the French practices of risk analysis and safety assessment of dams (2021) improves the impact of the EDD. This EDD approach is based on risk analysis which consists in identifying the sources of hazards, then the failure processes they initiate, characterizing the severity of the consequences and the probability of occurrence, and finally proposing risk control and/or reduction measures by prioritizing them, if the risk is deemed not to be controlled. Recently, the elaboration of recommendations for the justification of embankment dams and levees to erosion (edition planned in 2023) contributes to the deepening of the EDD but also of the design of new works, under examination by the Executive Commission of the CFBR.

New guidance in France on managing erosion risks associated with dams and levees

Let us recall the importance of the problem: erosion is the cause of more than 80% of large dam failures. Erosion covers all the phenomena of detachment and transport of individual grains by the hydrodynamic forces of underground flows in the body of an embankment structure or its foundation (internal erosion) and surface flows on an embankment structure or its foundation (external erosion). Four basic mechanisms are considered in the analysis of internal erosion initiation:

1. Concentrate leak erosion,
2. Backward erosion,
3. Contact erosion,
4. Suffusion.

Five main mechanisms are grouped by configuration in the analysis of external erosion:

1. Overtopping erosion caused by water passing the crest
2. Erosion or scour by longitudinal flow
3. Erosion due to flood discharge system malfunction
4. Erosion of the upstream face by wave impact
5. Erosion in particular situations.

It should also be remembered that the purpose of a hydraulic structure is to retain water. The failure is considered as the loss of this objective, i.e. an uncontrolled discharge of water. It comes from external causes, which the external functional analysis must list, and internal causes, related to failures of certain technological functions (embankment components, operation and management of safety devices), which are listed by the internal functional analysis. Among the main technological functions performed by the components of the structure, the safety functions are ensured by six passive design barriers:

1. evacuation,
2. waterproofing,
3. resistance,
4. filtration,
5. drainage,
6. protection of the faces,

and two active barriers:

1. monitoring,
2. intervention.

The justification of the erosion resistance of a structure thus consists in verifying that all these barriers are able to guarantee their contact functions (functional specification checks) and their flow functions (force transfer, continuity equation, etc.). The loss of a barrier or failure mode is the result of a chain of functional failures of components leading to the complete failure of the barrier. The justification of the structure therefore requires a study of the failures of each of the components ensuring a technological safety function. The failure or safety margin of a component is judged by the difference between the functional specification criteria of the barrier and the values of the component characteristics identified by the study. The objective of the justification studies is to demonstrate that the safety margins at the time of the study are sufficient with respect to the loads defined by the situation scenario. The scenario gathers:

- Normal situations for the predicted lifetime of the project.
- Rare or accidental situations: floods, leakage, pore pressure generation, chocks, and so on.
- Extreme situations: extreme flood and earthquake.

The evaluation can be done from a deterministic approach, a probabilistic approach or by expert judgement based on local and worldwide accident feedback. The approach then includes the following steps:

1. Appropriation of existing data by means of a preliminary documentary survey and visual inspection;
2. Identification of the studied profiles and all potential erosion paths;
3. Elaboration of the field models from the existing data completed by possible reconnaissance;
4. Choice of the scenario of project situations: inventory of loading combinations;
5. Qualification of the safety margin of the barriers along each potential erosion path for the studied situations;
6. Safety evaluation along each erosion path for the studied profile;
7. Summary of the erosion performance evaluation.

As the approach is new, the recommendations guide the reader to differentiate:

- Methodological recommendations based on the state of the art.
- Best practices, rules of thumb used by the profession, but for which scientific validation has not been found.
- New approaches proposed by scientific research, deemed relevant by those who have practiced them, but too recent to be validated internationally.

The approach departs from the Eurocodes justification in five main points:

1. The definition of the scenario of situations is set by the regulations. The situations to which the dams are subjected are chosen in accordance with the 2018 Technical Order on Dams defined by Authority. The situations to which the dams are subjected must be sufficiently representative to guarantee the levee system a level of safety with a probability of failure at most equal to 5% and a level of danger with a probability of failure of 50%.
2. The identification of potential erosion paths is comprehensive. Erosion resistance justification is produced along "potential erosion paths". The set of potential erosion paths must first be identified based on knowledge of field models. It is important to check the completeness of the set of potential erosion paths as a first step, and to justify the barriers against the actions of the study water for all failure modes and project situations.
3. The choice of justification. Depending on the nature of the available data, one of the three types of justification is used:
   a. no stress during the considered situation;
   b. no erosion during the considered situation;
   c. acceptable erosion in the sense of the serviceability of the structure during the considered situation.
4. The choice of two types of approaches. Two approaches evaluate the danger of failure according to different justifications and recommendations:

a. The deterministic approach is traditionally applied to dams.
b. The probabilistic approach, required by the regulation on dams, can also be adapted to dams. The knowledge of hydrological data series justifies the use of frequency probabilities, while the state of some components may require the use of subjective probabilities, and the results of some erosion tests pushes to develop semi-frequency probabilities, with a histogram reconstructed from some values.

5. The gradation of the approach. For the evaluation of internal erosion, three levels of analysis differ by the means implemented and the objective of result (urgency time).

Conclusions

The main cause of failure of embankment dams and dikes is erosion (internal and external, piping and scour). This phenomenon is not covered by the Eurocodes and requires a new approach to be controlled. The French Committee for Dams and Reservoirs is aware of this important issue and is about to issue recommendations to justify the resistance of hydraulic structures to erosion. These recommendations are preliminary. But they already give the engineer a tool that should allow him to improve the safety of his projects or his structures. The application of these recommendations will give rise to feedback in a few years to validate the final version.

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Photo. Restoration of spurs on the Oder River

River Basin Management Plans – for the third time

Water management plans are some of the most important planning documents in water management, the drafts of which are developed and updated every 6 years by the State Water Holding Polish Waters. Draft IIaPGW have been developed for each of the 9 river basin districts and adopted in 2023 through regulations of the Minister of Infrastructure. More than 25,000 activities have been planned for all of the water bodies nationwide. Their implementation serves to achieve or maintain good water status.

The third edition of the River Basin Management Plans (and the first one after the 2017 water management reform) are certainly more complete documents, perhaps it is even possible to use the term "mature", as they consider the lessons learned from the previous two planning cycles, as well as the recommendations of the European Commission. These are documents prepared based on a richer resource of data, as well as the results of analyses carried out in accordance with revised or updated methodologies. Comparing the new plans with their first update in 2016, not even mentioning the original plans, adopted in 2011, it is easy to see that they are more thoughtful, detailed, refined. Are they therefore more ambitious? Or easier to read? Let's look at the new water management plans and try to find an answer to these two questions.

Six years, for a five-year period

Pandemy of coronavirus has affected basically all aspects of our lives. It was also an indirect reason for the delay of the project on the second update of the river basin management plans (IIaPGWs). According to the schedule of the water management cycle and the provisions of the Water Law Act (transposing Article 13 (7) of the Water Framework Directive in this regard[1]), the adoption of the new edition of the plans should have taken place before 20 December 2021. However, they were finally published in the form of regulations by the Minister of Infrastructure between December 2022 and February this year; first for smaller river basin districts:

- IIaPGW for the Dniester river basin area (Journal of Laws 2022 item 2740) – 23 December 2022,
- IIaPGW for the Banivka river basin district (Journal of Laws 2023 item 86) – 11 January 2023,
- IIaPGW for the Nemunas river basin district (Journal of Laws 2023 item 114) – 16 January 2023,
- IIaPGW for the Elbe river basin district (Journal of Laws 2023 item 189) – 27 January 2023,
- IIaPGW for the Freshwater river basin district (Journal of Laws 2023 item 206) – 31 January 2023,
- IIaPGW for the Pregoła river basin district (Journal of Laws 2023 item 207) – 31 January 2023,
- IIaPGW for the Danube river basin district (Journal of Laws 2023 item 210) – 31 January 2023,

and finally for the two largest:

- IIaPGW for the Vistula river basin district (Journal of Laws 2023 item 300) – 16 February 2023,
- IIaPGW for the Odra river basin district (Journal of Laws 2023 item 335) – 23 February 2023.

The publication and entry into force the last of the nine regulations was the culmination of several years of work by many groups of experts carrying out successive planning work on behalf of and under the supervision of the State Water Holding Polish Waters (PGW WP), as well as its staff from the water planning departments of the regional boards and the National Water Management Authority, and under normal circumstances would certainly have been a source of pride. This time, however, they were rather accompanied by a feeling of relief, as the last weeks and even months before publication were a real struggle against time.

This delay means that the II aPGWs, which are strategic planning documents alongside flood risk management plans,

[1] Directive 2000/60/EC of the European Parliament and of the Council of 23 October 2000 establishing a framework for Community action in the field of water policy


Source: State Water Holding Polish Waters

drought plans and the marine water protection programme, setting out directions and objectives for water management in the broadest sense for the period 2022–2027, will in fact be in force for five years.

Thousands of pages, dozens of attachments. How to find one's way through this jungle?

Nine regulations on the II aPGW in total, comprise 88,733 pages of text, published electronically in the form of 99 files. The Vistula River Basin Management Plan, the largest by volume, comprises 50 files and almost 47,000 pages. The appendices can also be counted in hundreds, as the regulation for the Vistula River basin district alone contains about 86 of them. Some of these appendices are maps showing the location of water bodies in individual water regions, others are tabular lists, and there are also drawings and graphs. Could the content of these documents, and hence the regulations, have been reduced? No, because the content of the water management plan is defined by the already mentioned Water Framework Directive in its Annex VII and the Water Law[2] (Article 318 (1), (2), (4) and (6)), while the details are defined by the relevant regulation. However, while national legislation can be amended, it is the Directive that limits this, requiring each water management plan to include such elements as:

- a characteristics of the river basin district, including a mapping of the location and boundaries of the water bodies together with an identification of the reference conditions for each surface water type,
- a summary of the results of the anthropogenic pressure analysis,
- an identification of protected areas,
- information on the monitoring network and programmes,
- a list of environmental objectives together with a description and justification of the cases where derogations have been applied,
- a summary of the economic analysis of water use,
- a summary of the programmes of measures for improving the status of surface water bodies and groundwater bodies and for attaining the environmental objectives, with details of the complementary measures.

These guidelines are completed by the structure, adopted by the European Commission and the Member States, of the report on the water management plans that countries submit to the Commission to demonstrate compliance with the Directive (so-called compliance checking). Navigating through this maze of information, annexes, tables and images, especially in uneditable pdf files, is certainly an unfriendly activity with a high risk of failure. A simplification for all concerned will be the so-called water body charts, i.e. information on each water body collected in a uniform way and presented in tabular form. Such charts were first developed when the water management plans were updated, but this time a tool for their generation and review has been developed. A card for any waterbody can be downloaded using the site map or generated through filters. The tool is available on the apgw.gov.pl website, under Characteristics Cards.

What is new in comparison to the first update of the water management plans?

The first, immediately visible difference between IIaPGW and the first update of the water basin management plans is their number: there were 10 river basin districts and water management plans, in the latest version there are 9. Why? The Ücker river basin area, which was a kind of anomaly in our national planning, disappeared from the Water Law (Article 13) and which, due to its peculiarities (no watercourses within Poland's borders and thus no designated water bodies, monitoring programmes, action programmes, etc.), caused a slight smile and surprise among those reviewing and assessing national water management plan reports at the European Commission). The Ücker river basin itself has been included in the Oder River basin and, with this correction, the total number of pages of water management plans has been reduced by several hundred and the number of plans by one.

However, this is an organisational and formal change, so to speak, and much more important are the other differences between the two editions of the water

[2] Regulations of the Council of Ministers from 4 October 2019 on the detailed scope of the development of river basin management plans.

management plans, as they bring significant substantive and qualitative changes.

Firstly, the II aPGW introduces a new division of surface water bodies. On the one hand, this is a significant reduction in the number of river water bodies (by about 1,000) and an adjustment of the delimitation of coastal water bodies, and on the other hand, a verification of the lakes that should have the status of a water body. A circumstance accompanying this revolutionary change from the point of view of water management is the new typology of surface waters, introduced by the so-called Classification Regulation.[3]

Secondly, the new update of the management plans sets limits for good ecological potential, thus defining the environmental objective for artificial and heavily modified water bodies individually for each of them. It is noteworthy that this is the first edition of the management plans that organises the system of assessing the status of water bodies in this respect and thus represents a major step towards the comprehensive implementation of the concept of heavily modified water bodies.

The third major difference is the sorting out of derogations from environmental objectives. This applies The third to perhaps the most well-known derogation, the rationale for which is set out in Article 4 (7) of the Water Framework Directive (and Articles 66–68 of the Water Law Act). Indeed, while the use of derogations is de facto an explanation of the reasons for the impossibility of achieving the environmental objectives by the directive deadline (let us recall: December 2015) and a demonstration that the prerequisites set out in the directive exist, which in practice is supposed to remove from the state the threat of the European Commission initiating criminal proceedings for non-compliance with the directive, the derogation in Article 4.7 is something of an exception. This is because it is the only derogation attributed not to the water body as such, but to the planned investment. In other words: it is not a gateway to justify the non-compliance of the status of a water body with the environmental objectives attributed to it, but an agreement to introduce new physical alterations to that water body, which are likely to have a further negative impact on the possibility of achieving the environmental objectives. In the previous edition of the water management plans, it was the plans that decided whether a project with a potential or certain negative impact on the environmental objectives could be implemented (entry of the project in the water management plan with the derogation of Article 4.7) or not (non-listing). This has led to two closely related negative effects: firstly, the belief that "what is not in the plans, will not exist", and secondly, that the publication of the water management plan closes the possibility of implementing projects that are not included in the plan for six years. Regulations introduced by the 2017 amendment to the Water Law Act (Articles 425–440a) eliminate the chaos related to the formation of the derogation list and the uncertainty of investors as to its final shape. Currently, the procedure for granting a derogation is part of the water law assessment and takes place through an administrative decision, while the water management plan is a summary of the decisions issued. The IIaPGWs are the first edition of the plans in which this new system solution has been applied.

Finally, fourthly: the programme of activities. During the period of the original Water Management Plans and their first update, the actions to be implemented to achieve the environmental objectives were set out in a separate document, the National Water and Environment Programme. Since this edition of the water management plans, the programme of measures has been an integral part of them, thus defining by regulation the types of measures, their purpose, and the entities responsible for their implementation.

Action programme and exemptions for new projects

What do we find in this programme? A proposal of measures in the form of a national catalogue, containing measures to be implemented throughout the country, and a catalogue of measures assigned to specific water bodies (divided into primary and secondary). The former catalogue includes 171 measures grouped into 11 categories, while the latter includes 120 measures, grouped in specific groups for each water category. As a whole, the programme is therefore a comprehensive set of measures necessary to achieve the environmental objectives for surface and groundwater bodies – technical and non-technical measures (including education, inspections, analyses of the possibility of improving retention, adaptation to climate change, renaturalization, reclamation, etc.) that can have a positive impact on water status by preventing deterioration of water quality, protecting and improving habitats and eliminating or reducing anthropogenic pressures identified within water bodies. In total, the programme contains around 20,000 individual measures, allocated to individual water bodies respectively.

The fourth planning cycle so what next?

So, let's return to the questions from the first part of this article: are the IIaPGWs more ambitious than the previous update? Are they easier to read? The answer is no and no. And they do not have to be that way at all. The level of ambition is defined by the environmental objectives and the deadline for achieving them through the implementation of measures. Here, the limitations are organisational, human and financial capacities on the one hand, and the response time of the environment on the other. On the other hand, the accessibility of these documents because of content constraints cannot be achieved for legal reasons. Instead, additional tools, not part of IIaPGW, can be developed to review their content. This is what the water body maps are.

The second update of the plans is published, the roles in implementing their provisions have been defined. In parallel, the first activities of the work package on the planning documents that will form the basis for the third update have already begun. A new circumstance that will affect their content will be the inapplicability of Article 4(4) of the Directive, i.e., the time derogation for achieving environmental objectives. Thus, water management faces a difficult and (yet!) ambitious task of implementing a programme of measures, the effectiveness of which will determine whether Poland will be able to demonstrate success in achieving the goals of the Directive. One thing we can all be sure of: the time for learning the Water Framework Directive is over.

Przemysław Gruszecki
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State Water Holding Polish Waters

[3] Regulation of the Minister of Infrastructure of 25 June 2021 on the classification of ecological status, ecological potential and chemical status and the method of classifying the status of surface water bodies, as well as environmental quality standards for priority substances.

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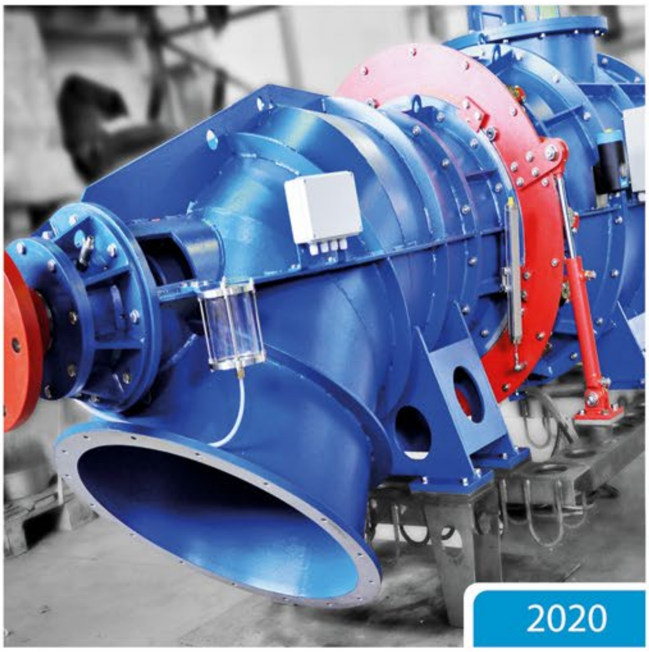
6x136 kW (d=1090mm, H=3.1m)

SHP San Secondo, Italy

1x92 kW (d=720mm, H=5.4m)



SHP Naviglio, Italy

1x84 kW (d=560mm, H=7.6m)

SHP Chancza, Poland

1x177 kW (d=590mm, H=11.9m)

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Inter-university Camp of Student Science Clubs Dychów 2023

On September 2–08, 2023, the second edition of the DYCHÓW 2023 Inter-university Student Science Clubs Camp took place. The project is implemented by the Student Science Clubs of the Warsaw University of Technology (SKN IskIErka, SKN Water Engineering and KN Energetics) and the Wrocław University of Environmental and Life Sciences (SKN Hydrologists and Hydrotechnicians).

From a historical perspective, water is, if not the oldest, then certainly one of the oldest, undisputed, and in the general consciousness, far underestimated, renewable energy source. If appropriate technical solutions are used, it is an ecological and stable source of energy, while enabling a significant reduction in CO2 emissions. The idea of organizing science camps for students of the Warsaw University of Technology (WUT) and the Wrocław University of Environmental and Life Sciences (WUELS) at the Dychów power plant was born many years ago, and it was materialized for the first time last year.

The following goals were set for the second edition of the Camp:

- **C1.** Carrying out measurements, research and observations of a scientific and educational nature related to the construction, operation and impact on the environment of the Dychów hydroelectric power plant complex (Lubuskie Voivodeship), in particular the largest pumped storage power plant (PSP) Dychów
- **C2.** Popularization of the best, reliable knowledge on hydropower among students of technical and natural universities
- **C3.** Stimulation and improvement of forms of activity of scientific circles as part of scientific and research cooperation with partners representing various sectors of the economy, administration and science
- **C4.** Development of cooperation skills within multi-disciplinary scientific teams
- **C5.** Integration of Student Scientific Clubs within the university and cooperation with other research centers

Course of the Camp

The Camp was attended by 19 participants (13 students and 6 supervisors) from WUT and 17 participants (15 students and 2 supervisors) from WUELS. The camp for students from Warsaw started on Saturday morning at 05:30. After nearly 500 km of travel, we stayed in the charming "Dwa Stawy" resort in Chromów. The next day was devoted to a detailed acquaintance with the facilities of the PSP Dychów, i.e. the beginning of the Dychowski Canal in Krzywaniec, the PSP Dychów itself and the lower reservoir of the WPP Raduszec Stary. On Monday we started field research. Students from the Faculty of Electrical Engineering and the Faculty of Mechanical, Power and Aeronautical Engineering of the Warsaw University of Technology installed and began testing the previously built measurement systems. Hydrotechnicians, representing the WUT and the WUELS, initially became acquainted with and assisted in the installation of measuring equipment and research, and in the afternoon they went to the area of the derivation canal, to a section run in an embankment, where they carried out the identification of filtration processes related to the impact groundwater canal. The observations included a detailed visual inspection, piezometric measurements in open piezometers included in the monitoring network of the power plant's hydrotechnical facilities, and identification of hydrogeological conditions using electrical resistivity tomography in connection with shallow research holes made to identify and assess the condition of the soil constituting the embankment and the foundation of the structure. The next day was devoted to hydrogeological research on the vent slope of the headwater dam of the PSP Dychów and the installation and calibration of measurement systems intended to diagnose the condition of the turbines. To identify water leaks, a short-range remote sensing method was chosen, based on the use of sensors to acquire data from a distance. A multispectral camera was used to determine the value of NDVI vegetation indices. Moreover, the appearance of hygrophilous plants (rushes, reeds) was observed.

Wednesday was devoted to an inspection of small hydroelectric power plants located near PSP Dychów. We started the tour from the WPP (Water Power Plant) Małomice, then we went to the WPP Żary I and II and the WPP Gorzupia I and II.

We devoted Thursday to continuing research and measurements carried out in the PSP Dychów building and on the hydrotechnical infrastructure structures and the upper reservoir of the power plant. On Friday, at the end, there was a working meeting summarizing the course and results of the Science Camp, in which all participants, supervisors, the Management of PSP Dychów and invited guests took part.

Research carried out

As part of the preparatory work before the start of the Camp, the following were carried out: two vibration and temperature measurement platforms. The systems were implemented based on 500 mA 32V vibration sensors, thermocouples and recording systems ensuring the acquisition and archiving of measurement results. In the case of the first measurement platform, the results were recorded using an edge computer collecting information from distributed measurement units based on programmable microprocessor platforms. The second platform was based on a modified e2TANGO field controller, recording signals from sensors and a PC computer working in the LAN network, acting as a data archiver. The system tests were carried out both in the Laboratory of Electrical Apparatuss and Switching Processes (Institute of Electrical Power Engineering, WUT) and in industrial conditions at the PSP Dychów.

The testing ground for hydrotechnicians was the section of the Bóbr river near Chromów, where a cross-section was created to test the geometry of the river bed and the flow speed using an electromagnetic hydrometric mill and specialized measuring equipment in the form of ADCP (Acoustic Doppler Flow Profiler). At 12.00 on September 6, a station was established to measure the physicochemical properties of water. The spot water sampling method used the previous day was extended into a 24-hour measurement, during which students assessed the variability of water parameters in a natural stream over the course of one day.

Additionally, the surface research team focused on measuring selected water parameters in the upper reservoir in three selected hydrometric verticals. At the locations of the hydrometric risers, additional samples of bottom sediments were collected for laboratory analyses. On the basis of own flow measurements and measurements of the PSP Dychów, the instantaneous efficiency of the pumping process was assessed with four operating pumping units of the PSP Dychów. The test results indicate high process efficiency.

The implemented measurement systems are the starting point for research work aimed at introducing innovative technologies and solutions for multidisciplinary monitoring of hydropower turbines. The use of various types of sensors and measurement techniques, such as advanced sensor technology, will allow for a comprehensive assessment of the condition of generators and building structures together with their surroundings, which is still a difficult challenge and usually goes beyond typical practices. The comprehensiveness and reasonable redundancy of solutions for monitoring such facilities will increase the level of credibility of facility condition assessments, earlier detection of possible threats, increase the level of reliability and costs associated with removing the effects of exceptional events that have not yet been identified.

Source: Dychów 2023 Camp archive

Photo. Commemorative photo of the Dychów 2023 Camp participants

Summary of the Camp

The organization of all kinds of camps and other projects of a scientific nature or supporting the educational process, both by universities and student scientific groups, carried out especially at real energy facilities, allows for the improvement of the knowledge and skills of future engineers, better awareness of the operation of the National Power System (NPS), and is also an important impulse to stimulate the need for professional and scientific development as well as planning and conducting research. Active observation of the operation of real generating units during operation allows for practical verification and better understanding of the essence of the acquired textbook and theoretical knowledge, while contact with the technical staff of such a unit is an excellent opportunity to draw on their experience and knowledge regarding the generating unit as well as the rules of conduct and good practices for NPS. We hope that the organization of subsequent editions of the camp will be an effective stimulus for increasing interest in scientific work among students, resulting in accelerated development and significant technological growth in hydropower. Closer contacts with energy companies may usefully support the process of searching and selecting an employee/employer for both parties involved.

The modern education system faces many new tasks and challenges. They are related to dynamic socio-cultural changes and technological development, resulting in the need to change the style of education of future technical graduates. The positive effect of such science camps is all the more visible. The described project effectively corresponds to the process of acquiring young talents for R&D work based on the formula of activity of scientific circles, especially in fields sought in the business environment (innovations using modern technologies in the energy industry).

Acknowledgments

The idea and goals of the DYCHÓW 2023 Inter-University Student Science Club Camp were warmly welcomed and supported by PGE Energia Odnawialna S.A., in particular the Management of PSP Dychów – Mr. Sławomir Szostak and Jarosław Borodynko. At all times, we could count on detailed and competent consultations, access to the devices, structures and installations of the PSP Dychów and any other assistance necessary for the safe and careful implementation of the work plan. We would also like to thank Mr. Mariusz Dudziuk, Director of the Run-of-river Hydro Power Plants Operations Office, and Ms. Julia Trymucha, Head of the Management and Operations Department at PGE Energia Odnawialna S.A.

We would like to thank Elektrometal Energetyka S.A. for building a special e2TANGO field controller, used for the acquisition of measurement data.

This year's edition of the camp received funding under the "Excellence Initiative – Research University" program implemented at the WUT.

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Methods for protecting surfaces against cavitation erosion

In fluid-flow machines, it is possible to distinguish areas with increased intensity of flow disturbances or increased flow velocity. The cause of the disturbances is often flow separation from the streamlined surface and the generation of vortex structures with cores featured by an abrupt increase in the flow velocity. An increase in the flow velocity can also occur at the streamlined surface itself – e.g. in narrowings of flow channels. As it is apparent from the energy conservation law (Bernoulli's equation), in both cases there is a decrease in static pressure which can sometimes take even negative values.

In ordinary tap water or in open rivers and channels, a pressure decrease below the saturated vapour pressure generally leads to the growth of cavitation nuclei (microbubbles) present in the liquid. The growth of microbubbles is initially quasi-stationary, but becomes explosive after reaching a certain critical size. Conversely, an increase in static pressure causes growth inhibition, followed by its nonequilibrium (implosive) collapse. A cycle of these phenomena is referred to as cavitation from the word cavus (Latin: hollow). Such a cycle can, of course, occur not only in the flow, but also in the acoustic field, where tensile and compressive stresses occur interchangeably. Cavitation bubbles can disintegrate and merge to form quite complex vapour-gas structures. The formation of closed vapour-gas caverns, usually attached to the streamlined surfaces, is also considered cavitation. Their explosive growth is prevented by pressure which, outside the phase-separation interface, takes a value greater than the saturated vapour pressure.

According to the content of the gas phase, the following types of cavitation are distinguished:

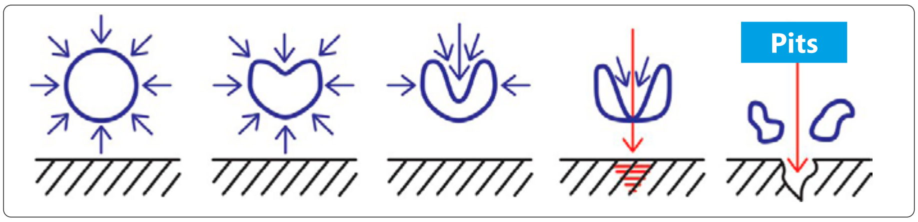
- Vaporous cavitation that develops at pressures close to the saturated vapour pressure of a liquid at a given temperature. The bubble is filled mainly with vapour of the given liquid.
- Gaseous cavitation, during which bubbles grow mainly due to diffusion of gas from the liquid into the bubbles.
  - Gaseous cavitation is often considered no cavitation at all, because bubble growth, in this case, is quasi-stationary and not explosive, and the process of bubble decay is rather slow and largely connected with gas diffusion into the surrounding liquid.
  - A characteristic feature of the decay process of a bubble with a high content of gas other than the surrounding liquid vapour is bubble pulsation before the final collapse. In a closed cycle, the products of the collapse can serve as nuclei of the next cavitation process.
  - According to the manner of inducing pressure depression below the critical pressure, the following types of cavitation can be distinguished:
- Hydrodynamic cavitation: resulting from the static pressure of a liquid dropping below the critical pressure. This decrease may be caused by a local increase in flow velocity or a change in external conditions.
- Acoustic cavitation: resulting from a local pressure drop caused by an acoustic wave propagating in the liquid.

Further classifying divisions are largely related to the form, as well as the mechanism and dynamics of the development of cavitational formations (e.g. bubble cavitation, cloud cavitation, vortex cavitation, tip vortex cavitation, axial vortex cavitation, sheet cavitation, attached cavitation, strip cavitation, pulsed cavitation, pseudo-supercavitation, supercavitation, etc.).

Course and consequences of cavitation erosion

Cavitation interaction with the streamlined solid surface is dynamic and often leading to vibration and erosion phenomena – including threats to the integrity of machinery and equipment. What is essential for the initiation of cavitation processes is the presence of gas microbubbles which represent natural cavitation nuclei and the mechanism of their initiation in the liquid (nucleation) – especially at the flow confining surfaces of solids or particles floating as contaminants. The evolution of a typical cavitation bubble involves several stages. The initial phase of development begins with quasi-stationary growth which lasts until the bubble reaches a certain critical size, after which non-equilibrium (explosive) growth takes place until further growth is restricted and inhibited by external factors – usually an increase in the pressure of the surrounding liquid, which, in the next phase, leads to reduction in the size of the bubble and its implosion. If the flow confining surfaces in a fluid-flow machine are in direct vicinity of the collapsing bubble then they are exposed to the mechanical impact of implosion. The local stresses acting on the surface due to implosion can reach up to several gigapascals. This is a level of stress that exceeds the yield strength of most metals and structural alloys, and it is for this reason that gradual but steady detachment of surface material particles is observed. This is a mechanism called cavitation erosion which, of course, in the context of the durability of the eroding surface, is (with some exceptions) an undesirable process. Why such a great capability to induce destructive stresses in the surface (surface layer) of metals?

Firstly, the sheer nature of the cavitation phenomenon, namely the cyclic sequence of events, i.e. the growth, collapse and implosion of bubbles, is responsible for fatigue wear effects, and secondly – which is in fact the main destruction mechanism – the implosion pressure, although short-term, reaches enormous values from several hundred to several thousand megapascals! The implosion of a single bubble lasts a very short time, fractions of microseconds, and is the final phase of the process of cavitation bubble collapse. The liquid surrounding the imploding bubble moves at tremendous speeds of 100–200 or even up to 500 m/s. Its deceler-



Source: Belse Ltd. archive

Fig. 1. Cavitation bubble collapse course with implosion in the final stage of the process

Source: Laboratory of fluid-flow machinery VOITH Turbo Ltd.

Photo 1a. Test rig used for establishing the cavitation erosion initiation period of a streamlined surface

Source: Laboratory of fluid-flow machinery VOITH Turbo Ltd.

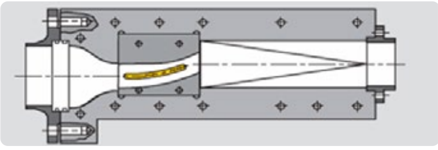


Photo 1b. Longitudinal section of the flow module channel in the test rig of Photo 1a. Sample subjected to cavitation marked in yellow

ation causes colossal spike in pressure values due to the phenomenon of hydraulic shock. It is something resembling "thunder and lightning" (incidentally, sometimes flashes of light are generated during cavitation) and this state has consequences for the equipment. If the implosion occurs in the immediate vicinity of a wall, the symmetry of the phenomenon is disturbed, the bubble is deformed and a cumulative jet is formed which pierces the surface of the bubble and hits the wall at a very high speed. By this time the bubble has already deformed into a torus, which then undergoes further collapse and final implosion (fig.1).

Corrosion and cavitation damage

In summary, cavitation is a phenomenon caused by a pressure change in a liquid, involving the initiation, growth and decay of bubbles containing vapour of a given liquid, gases dissolved in it or a liquid-vapour mixture. This process causes cavitation erosion due to implosion of bubbles near or directly on the surface of the eroding material. The effects of cavitation erosion were already observed in the end of the 19th century in water turbines and ship propellers, yet at that time surface cavitation damage was still interpreted as the result of a special type of corrosion. Phenomena such as corrosion and cavitation occur simultaneously and can even "fuel" each other. Cavitation erosion generates a current of few milliamperes whose source may be, in particular, electrochemical phenomena (corrosion) associated with detachment of metal particles and the penetration of hydrogen ions. On the other hand, corrosion products change the surface structure and, as they are poorly bonded to the surface, easily spread into the liquid, constituting solid particle contamination.

Surface irregularities and particle contamination can cause nucleation of cavitation bubbles in the flow. Therefore, we are dealing with zones where surface damage will clearly be caused by cavitation, zones dominated by corrosion effects and areas of mixed wear. The intensity and nature of bubble nucleation at the liquid–solid interface are also dependent on the free energy (or surface tension) of the solid surface. Smooth surfaces with low free energy, close to the free energy of the liquid (for water it is approx. 70 mJ/m² at 20°C), i.e. hydrophobic surfaces, help to reduce the likelihood of cavitation bubbles development, which in turn leads to mitigation of erosion. Smoothness, hydrophobicity and susceptibility to hydrodynamic impact by the wave caused by implosion are surface characteristics showing a direct impact on erosion resistance of structural materials.

Performance tests of protective coatings

Abundant operational experience shows that the use of composite materials for filling erosion pits and creating protective coatings provides the expected result of extended service lifetime. This is also confirmed by laboratory tests and by tests carried out at special installations (photo 1a and 1b). Tests under conditions of advanced cavitation determined the time after which erosive damage would appear on the surface of the test material sample. And so, for alloy steel with chromium and nickel additives (Cr-Ni 134 "Turbine Alloy"), the first erosion pits occurred after approx. 470 hours of testing, while no pits were observed at the sample of Belzona®2141 composite, even after 500 hours of testing under the same conditions. Therefore, the polymer composite exhibits higher durability against the phenomenon of cavitation erosion than alloy steel.

This effect was also confirmed by tests conducted in the laboratory of the Faculty of Mechanical Engineering and Ship Technology of the Gdańsk University of Technology. This time cavitation was induced ultrasonically in a vessel without liquid flow (photo 2). The aim of the research was to test the resistance of different materials to erosion under conditions of cavitation generated during drilling. The comparative analysis included, inter alia, durability of the P110 steel (with the following alloying additives: 0,26% carbon, 0,19% silicon, 1,37% manganese, 0,148% chromium, 0,028% nickel and others) and the Belzona®5831, 1321 and Belzona®2141 composites. The test results are summarised in figure 2. The erosion curves represent mass loss (in grams) as a function of the exposure time in the cavitation environment – the higher the mass loss, the lower the material erosion resistance. The erosion curve of Belzona®2141 composite almost lies on the x-axis of the graph, which proves very good resistance of the material, even better than that of the P110 steel. Even alloys of "softer" and more malleable metals, so-called hydron-

Source: Ł. Bolewski, M. Szkodo, M. Kmieć, PG

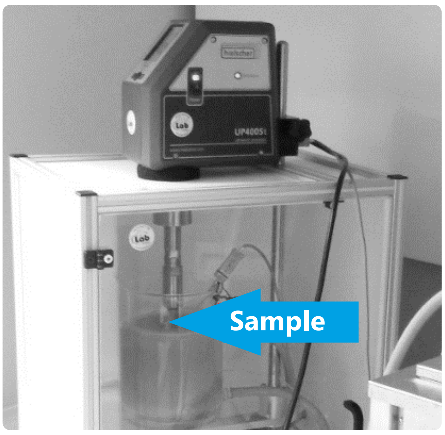


Photo 2. Laboratory rig for testing material resistance to cavitation by means of the vibratory method

Source: Ł. Bolewski, M. Szkodo, M. Kmieć, PG

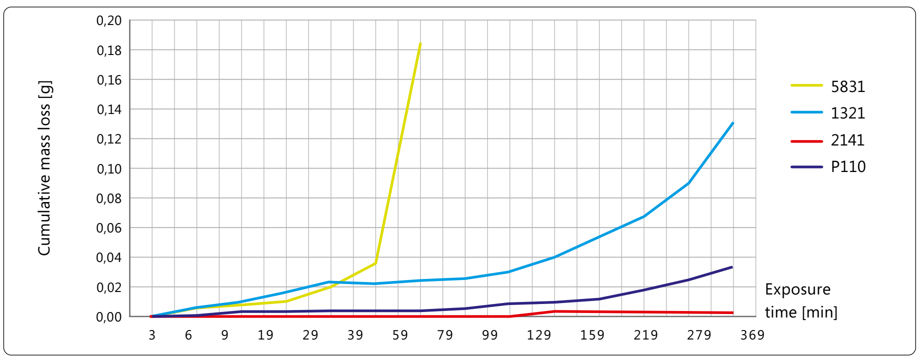


Fig. 2. Erosion curves determined by means of a cavitation test in distilled water

Source: Laboratory of fluid-flow machinery VOITH Turbo Ltd.

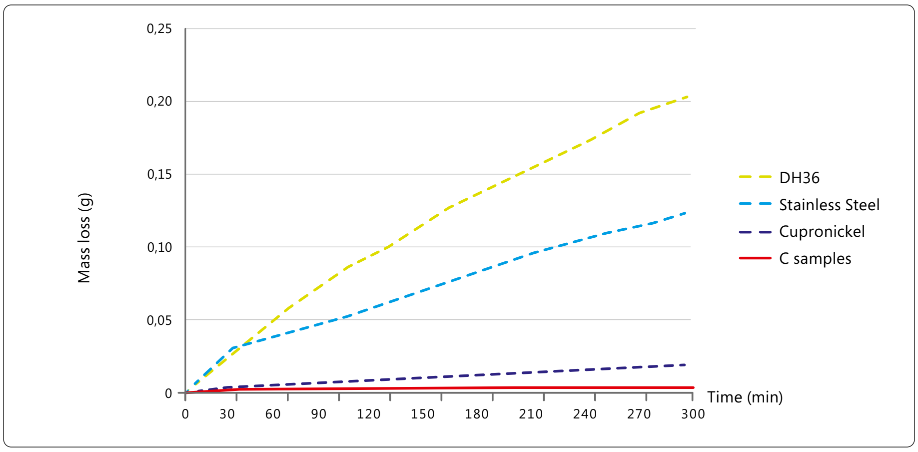


Fig. 3. Erosion curves of metal alloys and the Belzona®2141 composite (C samples) after 5 hours of cavitation exposure

Source: Laboratory of fluid-flow machinery VOITH Turbo Ltd.

Photo 3a. Sample of Cu-Ni alloy. View after exposure at the vibratory test rig

Source: Laboratory of fluid-flow machinery VOITH Turbo Ltd.

Photo 3b. Sample of the Belzona®2141 composite. Post-exposure view

Source: Belse Ltd. archive

Photo 6. Pump body after filling the pitting with the Belzona®1311 composite, rehabilitation by means of the Belzona®1341 coating and applying Belzona protective coating

Source: Belse Ltd. archive

Photo 4. Belzona®2141 coating used to protect ship rudder and propeller against cavitation

Source: Belse Ltd. archive

Photo 5. Cavitation pitting in the surface layer of the pump body

als, e.g. Cu-Ni and Al-CR, used in shipbuilding and hydraulic civil engineering due to their high resistance to cavitation and corrosion, have not reached the durability level of the Belzona®2141 composite coating in erosion tests. The erosion curves were determined from the results of tests in which cavitation was induced by an acoustic field of 20 kHz frequency. In addition to the Cu-Ni alloy (cupronickel curve on the graph) and Belzona®2141 (sample C on the graph), DH36 steel known as shipbuilding steel (C-0.18% Si-0.10% Mn-0.90% CR-0.20% Ni-0.40% Cu-0.35%) and conventional alloy steel (stainless steel) were also tested (Fig. 3). Photos 3 a and b show post-exposure view of the samples. At this test rig, located at the laboratories of City University of London, the cavitation exposure duration of each sample was 5 hours. Each sample was carefully weighed before the test and after each test interval. The results are summarised in figure 3.

Source: Belse Ltd. archive

Photo 7. Water turbine runner blades covered with Belzona®1341 and Belzona®2141 hydrophobic and anti-cavitation coatings, respectively

Conclusions

Cavitation as a phenomenon consisting in development and collapse of local flow field discontinuities, and releasing substantial energy packages that strike the solid surface in form of short duration pressure pulses, is a real "water cannon"! It seems, based on experiments and applications, that a surface is the more resistant to the impact of such "water shots", the more it is able to absorb the energy of these impacts without triggering destructive stresses in the material. Such an effect can be provided by a polymeric material, in particular Belzona®2141, which – thanks to its elasticity – shows good capabilities of relaxation and dissipation of energy. Both features complement the erosion and corrosion resistance of metal parts of machinery and equipment such as: ship propellers and rudders (photo 4), runner blades and other components of water turbine flow systems, impellers and impeller pump casings (photos 5, 6, 7) and many others.

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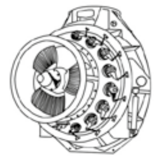

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Direct line – a rescue or untapped potential?

Poland needs new renewable energy generation capacity, but the current grid situation, outdated regulations for grid connections that are not adapted to current market realities, practices of distribution system operators, and many other factors are slowing down the development of renewable energy sources (RES). A direct line could be a remedy for these problems.

Electrifying the economy while achieving net-zero emissions by 2050 is a topic that keeps many EU member states' governments awake at night. The growing demand for electricity, sustainability obligations for businesses and EU climate goals are just some of the challenges currently facing various types of enterprises, not only in the energy sector. To meet these challenges, it is necessary to implement appropriate tools in the legal frameworks of member states that allow for effective transformation processes while optimizing costs.

Industry needs and system capabilities

The energy crisis and the resulting sharp rise in energy prices have led to increased business risks and a general sense of destabilization in many companies. However, energy-intensive enterprises are particularly sensitive to significant changes in electricity prices. Due to the high energy consumption of large industrial plants, the current direction of EU policy regarding sustainable development reporting, as well as the necessity to meet conditions for financial support, businesses require significant amounts of affordable, green energy.

However, it should be noted that the rapid development of distributed energy poses a threat to the security of the grid. Moreover, a significant problem for obtaining new RES generation capacity is currently the issue of refusals to conclude grid connection agreements. According to the latest report from the President of the Energy Regulatory Office in Poland (ERO) from June 2023, ERO's regional branches received nearly eleven thousand notifications of refusals to connect facilities to the power grid in 2021 and 2022 combined. This represents almost nine-fold increase in refusals compared to the previous reporting period (2019–2020) when there were just over 1,200 notifications.

How to eliminate these threats?

The solution to current problems, not only in the energy, but also in the industrial sector, could be a direct line, which, in simple terms, aims to connect the electricity producer directly to the consumer, bypassing the grid infrastructure. Why could it be, not will it be?

The law under which the regulation for direct lines is designed came into force on September 7, 2023. The mechanism is provided in two variants: island and grid. The island variant involves connecting an isolated generation site with an isolated customer for the direct supply of electricity to that customer. According to the regulations, an isolated generation site is a unit from which all generated electricity is directly supplied to an isolated customer. An isolated customer, on the other hand, refers to a consumer who is not connected to the power grid or is connected in a way that prevents the introduction of electricity generated in an isolated generation site into that grid or meets certain conditions, technical requirements and obligations specified in the law, including obtaining a concession for electricity trading.

The second variant involves connecting a generation unit with an energy company other than the one generating electricity in that unit, operating an electricity trading business, for the direct supply of electricity to their own facilities or to consumers connected to the grid, devices, or installations of those companies.

Introducing electricity into the grid

One of the provisions of the law states that energy consumption via a direct line does not limit the consumer's right to connect to the grid and to receive electricity from that grid on the terms specified by the law, provided that their devices or installations prevent the introduction of electricity supplied via the direct line into the distribution or transmission grid to which the consumer intends to connect. However, there is an exception to the restriction on introducing electricity into the system, but only on the consumer's side. For the electricity supplied through the direct line to be introduced into the power grid, the consumer must meet certain conditions for connection and technical requirements specified in the law, as well as possess a concession for electricity trading. In the island variant, there is no possibility for the producer to introduce electricity into the grid.

EU Directive

It should be noted that in the current legal framework in Poland, the Energy Law already includes a definition of a direct line. The amendment of the Energy Law, which includes a new definition and adjusted regulations, implements the EU directive from 2019. According to this directive, every electricity producer and supplier has the right to direct supply of electricity through a direct line to their own premises, subsidiaries and customers. Furthermore, every consumer has the right to procure electricity through a direct line.

The directive also provides that member states shall take the measures necessary to enable all producers and electricity supply undertakings established within their territory to supply their own premises, subsidiaries and customers through a direct line, without being subject to disproportionate administrative procedures or costs;. The regulation shall also allow all customers within their territory, individually or jointly, to be supplied through a direct line by producers and electricity supply undertakings.

Regulatory barriers

Analyzing the content of the EU regulation and the provisions implemented into the Polish legal system, it is evident that the Polish version of the direct line has certain barriers preventing its wide application. The necessity of involving an electricity trading company in the grid variant represents both a financial and administrative barrier. In the island variant, the requirement of obtaining a concession for electricity trading to introduce surplus electricity into the grid is necessary for the companies that are not professional energy market players, and their goal is not to sell electricity – as they may only want to reduce costs and increase the share of green energy in overall consumption.

In addition, this construction of the regulation discriminates against RES technologies benefiting from support systems (FIT/FIP or auction), for which the condition for participation in the support system is to directly introduce generated electricity into the grid. This is the case, for example, with biogas plants and agricultural biogas plants.

Who will benefit from the direct line?

The direct line will certainly be a very good solution for optimizing costs and accelerating decarbonization processes for the largest companies (including energy-intensive ones), especially if they have a concession for electricity trading or adequate financial collateral to obtain it. However, regulatory barriers will affect not only small or medium-sized entities but also large production plants for which no such mechanisms to reduce electricity bills or increase the share of renewable energy are provided. This is regardless of whether the use of more green energy is aimed at obtaining financial support, fulfilling obligations resulting from EU policy, or implementing corporate image strategies.

Paulina Grądzik
Expert on Legislation and Energy
Lewiatan Confederation

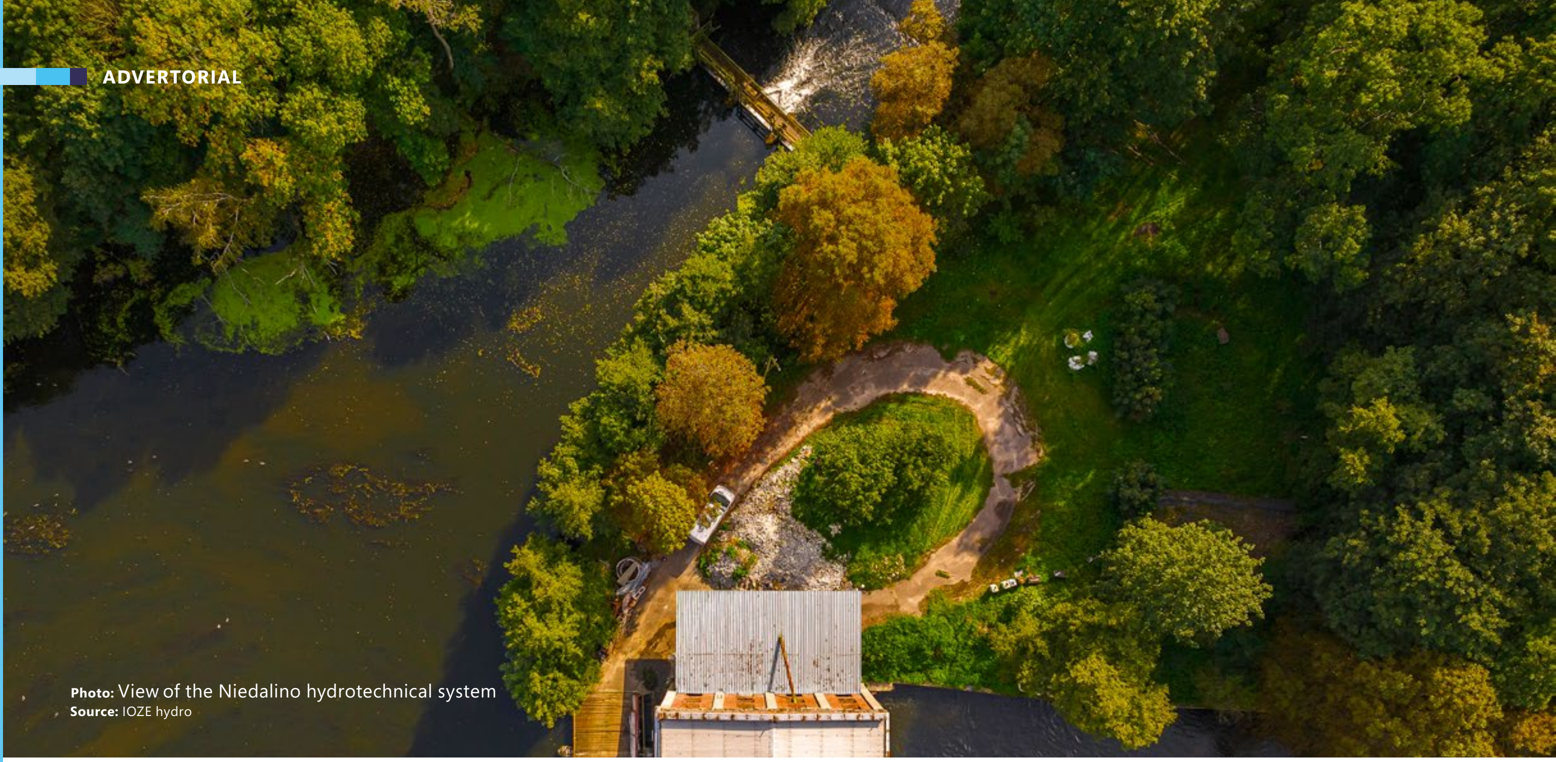


Photo: View of the Niedalino hydrotechnical system
Source: IOZE hydro

An old watermill's new soul – the Niedalino SHP

In Niedalino, on the busy River Radew, there is a more than 120-year-old watermill building that houses a small hydropower plant (SHP). This year, thanks to the efforts of the current owner and the IOZE hydro team, the power generator system was replaced, giving the SHP some new technical panache. Below is an account of the work carried out, with comments from the developer and those responsible for the implementation.

When researching the watermill's history (its German name is *Wassermühle mit Kraftbetrieb, Kammele – Nedlin*), one is likely to come across information that it was built between 1900 and 1901 by the von Kameke family, local landowners who lived near Niedalino from around 1600 until 1945 (when they were forcibly relocated to Germany). A few years later – in December 1949 – the watermill was taken over by the People's Republic of Poland Government under the Ruling of the Minister of Internal Trade[1] and was managed for the next several decades by the Polish Grain Plant in Stoisław. It served as a wheat mill with a throughput of 60 tonnes per day. Over the years, the watermill's drive was modified to include a hydroelectric system, with the facility operating two Francis turbines – a larger 125 hp turbine, as well as a smaller one with an output of 53 kW. The building and its equipment have been renovated several times during their lifespan.[2]

In 2001, the watermill ceased operations and was put up for sale. This is how it ended up with the current owner, who has converted it into a power plant using the existing on-site infrastructure and began to generate electricity as "Niedalino SHP".

¹ Monitor Polski (Official Gazette of the Republic of Poland) No. A–5/ item 55, Ruling No. 5 of the Minister of Internal Trade of 7 December 1949 issued in consultation with the Chairman of the State Economic Planning Commission on the transfer of enterprises to State ownership.

² http://www.rosnowo.pl/mlyn-niedalino.html

THE SMALLEST AND OLDEST IN THE CASCADE

The Niedalino SHP is part of a cascade of hydropower plants that also includes the Energa Group's Niedalino Hydropower Plant built in 1912 (370 kW capacity) and the Rosnowo Hydropower Plant built in 1922 on the Rosnowski Canal (1.1 MW capacity). All plants cooperate with each other; this allows the Niedalino SHP's staff to receive data on the water discharge schedule from the Niedalino HP manager.

The close proximity of the run-of-the-river power plant built at the dam at Lake Hajka (a.k.a. Lake Niedalino) ensures that the flows directed to the Niedalino SHP turbine units remain stable. However, replacing obsolete, low-performance technology was a necessary step to maximise the facility's potential.

Though the building is not formally under conservation protection, its historical value is undeniable. Consequently, the

Source: www.rosnowo.pl/mlyn-niedalino.html

Source: IOZE hydro

Photo: Niedalino watermill in 1901 and today

Source: IOZE hydro

Figure: Location of hydropower plants along the Radew River's cascade

Source: IOZE hydro

Photo: Bringing the turbines inside the watermill

modernisation effort had to be carried out carefully and with respect to the age-old architecture of the building. Today, it can already be said with certainty that the venture has been a success. At the time

Łukasz Gołąb, IOZE hydro Installation Manager:

Although the turbine installation work at the Niedalino SHP facility went very smoothly, it involved some eccentricities. Using this word is no coincidence: at certain points, we had to manoeuvre the large, several-tonne turbines with precision to within a few centimetres. We brought the turbines into the watermill building through the front door. For this, we used a metal framework sliding on rollers. Next, we used metal ceiling beams to suspend the turbines and place them in the prepared assembly positions. The concrete draft tubes were undercut to accommodate the new metal draft tubes. We replaced the old German-made electricity infrastructure with four modern automation and control cabinets. The Niedalino SHP was one of those projects where well-thought-out in-house installation logistics and a flexible approach to any arising difficulties were crucial. Still, given the numerous power plants we have worked on so far, there has not been a technical obstacle that we have not been able to overcome.

of writing, the Niedalino SHP has already been feeding electricity from the operation of the new generator system into the grid for more than a month.

A DEMANDING INSTALLATION PROCESS

Like many recently modernised power plants, the Niedalino SHP belonged to a group of facilities for which the prospects in terms of supporting electricity sales had ended. What ultimately prompted the owner's decision to upgrade was the stabilising new legislation related to RES. The legislation still makes participation in the guaranteed 15-year support scheme (under the feed-in tariff scheme) conditional on the construction of a new system. This corresponded with a pressing need to improve the facility's performance and improve its operators' comfort. The modernisation work was undertaken by the IOZE hydro team. The primary tasks involved dismantling the two existing hydrosets and installing two new ones, implementing a new control and automation system, as well as renovating the concrete surfaces of the inflow chamber and part of the machine room floor.

New technology brings a breath of fresh air

The upgrade involved replacing two obsolete Francis turbines the facility had used for decades with two horizontal Kaplan turbines, each with the capacity of 75 kW and a rotor diameter of 1050 mm. This kind turbine is equipped with a rotor that can be adjusted during operation and guide vanes that work by using a hydraulic control system with a hydraulic power unit. This makes it possible to actively control and adapt the entire hydrounit's operation to the current water flow conditions. The turbine is also accompanied by a hydraulic accumulator to protect it during an emergency shutdown. A belt transmission has been installed to transfer power from the Kaplan turbine to the generator. All equipment installed at the facility has been manufactured by IOZE hydro. In terms of facility automation and control systems, IOZE hydro has opted for its proven solutions; these are described in greater detail for the purposes of this article by IOZE hydro's Chief Automation Officer.

Source: IOZE hydro

Photo: One of the two new generator systems at the Niedalino SHP

Jan Tuschik, owner of the Niedalino SHP:

I have been a member of the Polish Association for Small Hydropower Development (TRMEW) for years and, through behind-the-scenes conversations with other Society members, I found out that IOZE hydro could expertly modernise my power plant. The result of the work is not only modern turbines but also improved user comfort at the facility, the body of which has not been affected in any way.

At present, the only work to be done by the power plant staff is keeping the trash rakes clean while I remotely monitor the operation of the turbines on my mobile phone. One month after commissioning, I am happy to say that the plant is working properly – we have completed the commissioning period and are generating the expected energy output.

Apart from delivering the technological portion, IOZE hydro gave me tangible support in handling all the paperwork for the project, as well as obtaining a certificate from the Energy Regulatory Office to enable the sales of unused electricity for the next 15 years under the feed-in-tariff scheme. I know that the procedure to obtain the certificate requires appropriate formal preparation and a great deal of diligence to succeed. At the same time, this form of subsidy ensured an acceptable rate of return on the investment project.

Source: IOZE hydro

Photo. A hydraulic unit, new control cabinets and historical elements of the mill equipment in the background

Sebastian Wites, Chief Automation Officer at IOZE hydro:

The Niedalino SHP has seen a tremendous technological leap as a result of its modernisation. We replaced the purely manual power plant controls, utilising pre-war German-made equipment, with modern and intuitive equipment.

We supplied the Niedalino SHP with two complete hydrosets with asynchronous generators. Due to the type of generators used, the system was fitted with a reactive power controller. Each of the hydrosets can operate either autonomously or controlled by a master controller. The control system is based on separate PLCs and 10-inch touchscreen operator panels for each machine. If one of the hydrosets fails, the other takes over the function of regulating the water level or flow, depending on the selected mode of operation. Besides electrical parameters, the controllers monitor such parameters as rotational speed, vibration and a range of temperature readings from all generator and turbine windings and bearing nodes. The facility has also been fitted with temperature sensors in the switchgear and the turbine house. The headwater levels – upstream and downstream of the grating – and tailwater levels are measured, so we have information on the gross head and the head at the inflow grating of each hydroset. In addition, we also read the power hydraulics pressures, the position of the drive belt on the pulley, the position of the turbine apparatuses and the current flow. The facility has been equipped with a remote access solution in the form of a SCADA visualisation system. It allows us to generate reports from different periods. Safety control system settings can be changed, and advanced diagnostics performed, separately for each hydroset, including remotely in the latter case. Operators can access reports on all measured parameters, generated as tables or graphs, either separately for each hydroset via operator panels or using the SCADA system. This is an indispensable source of knowledge about the facility's operation, which enables such things as timely prevention of serious failures and optimising device operation.

Changes are coming

Currently, pursuant to the Regulation of 9 November 2022, the reference price for hydropower plants with a capacity of less than 500 kW is PLN 770 per MWh (indexed annually for inflation).

The certainty of electricity sales at a guaranteed price, independence from energy market fluctuations and forecast price drops, as well as a relatively short formal and legal process, encourage SHP owners to modernise their facilities under the current legal conditions. Access to modern, high-efficiency hydrounit technology, able to run at the optimum operating point and offer greater availability and reliability, ensures increased electricity generation. Combined with higher electricity sales prices, this offers SHP owners a highly attractive investment opportunity and peace of mind for many years to come. Unfortunately, the proposed legal changes are set to introduce significant restrictions. It is worth taking advantage of the currently available opportunities before these changes come into force.

The IOZE hydro team is looking forward to fully refurbishing further SHPs.

Wioleta Smolarczyk
Łukasz Kalina
IOZE hydro

Photo. Visualisation of one of the variants of Tolkmicko PSH

Source: Neo Energy Group

On the lookout for locations for new energy storage facilities – Tolkmicko PSH project

Pumped storage hydropower plants (PSHs) are one of the most efficient, large-scale storages of energy that can additionally be accumulated over a very long period of time. Renewable energy sources account for an increasing share of the National Power System. It is therefore not surprising that there is increasing talk of further PSHs being built in Poland. A perfect example of this is the planned investment in the Tolkmicko PSH.

In the near future, the picturesque and charming Tolkmicko, located in the Warmian-Masurian Voivodeship, may become another important facility on the map of Polish hydropower. Courtesy of NeoEnergy Group's Chief Operating Officer, Jacek Rusiecki, we were able to find out more details about this investment. The aforementioned company is the main developer of the project, which undoubtedly represents one of the most interesting concepts in hydropower in recent years. It is also worth mentioning that for years now, wind energy has been developing rapidly in the Baltic Sea. We are witnessing the rapid development of offshore wind projects. We may soon have a problem balancing these generation sources. We even asked our interlocutor whether there are plans to cooperate the companies that will carry out these projects? The answer is obvious. Tolkmicko PSH will also be built to complement offshore projects. For that purpose, we are in talks about a joint venture with the ORLEN Group, which has offshore wind farm projects in its portfolio.

Genesis of the project

The history of this project was born during the environmental studies carried out for the project to cross the Vistula Spit. Our interviewee used to be Vice President of the Management Board of PGE Energia Odnawialna, responsible for its entire hydroelectric power sector, including pumped storage power plants. Already at that time he came into contact with the Tolkmicko PSH project. The owners of the project approached PGE Energia Odnawialna with a proposal to cooperate on the PSH concept. However, this did not materialise for various reasons. When he began working at Neo Energy Group, he returned to the idea. This made it possible to start work on the idea in mid-2021.

"*The first time I encountered the pumped storage power plant project was when I was still working at PGE Energia Odnawialna. The people preparing this project initially presented it to us. At that time, there was no demand for this project and no further work was pursued. After I changed jobs, I looked for a contact for these people. I found out that they were not able to find a partner that was interested in this. We decided to join forces and test this project. It took a while before we agreed on the terms of cooperation, but as of mid-2021, practically speaking, we are working on it together.*"

The construction of the pumped storage power plant in Tolkmicko is expected to have a positive impact on the balancing of the Polish energy system. Up to now, there have been various problems which unfortunately may grow, but with this project there is a chance that there will be fewer of them. However, the need to have a solution is stronger . In our conversation it was highlighted that there will be some exemptions. By now more sources are being developed, more sources that can operate at a lower intensity, but an investment of this scale will be very useful. The development of different sources of renewable energy also has a part to play in this.

Reactions of the community to the planned investment

The project to build pumped storage power plant is one of the largest investments in Polish hydropower sector in recent years. Neo Energy Group has actively started working on the project and the local community has welcomed it. The Municipality, with whom discussions were held regarding the change of the local zoning plan, reacted positively to the activities, but the procedure for changing the plan itself is very long and complicated. As our interlocutor mentions, these areas are not wealthy and therefore any infrastructure devel-

Planned technical parameters:

- reservoir area – approx. 144 ha
- reservoir volume – 25 million cubic metres
- installed capacity – approx. 1,000 MW
- turbines – 3 or 4 Francis turbines, each with an installed capacity of approx. 200 MW
- pipelines – 3 or 4 of approx. 7 km length
- operation time – more than 7 hours in turbine mode
- reservoir storage capacity – 120 GWh

opment is a new opportunity for them to generate additional income and create new jobs. However, as with any major investment, there were some doubts.

"As far as the residents of the adjacent settlement are concerned, I even got such an email from a concerned resident about the fact that we will be displacing them. So, I wanted, therefore, to reassure her that the assumption we have made does not allow for mass displacement".

It was for this reason that of the three area options considered, the smallest one (area 144 hectares) was decided upon. This decision was driven not only by the costs would generate by the investment, but also to reduce public non-infringement of peace. In the areas where the investment is planned, there are 3 facilities whose owners have no objection to their being used for this project.

Tolkmicko PSH – the realisation process

The implementation of this project is a demanding process, but in the initial phase of its formation, there are few people involved. There are three people in the development team itself, but as the developer mentioned to us, this will be expanded when the work is more advanced. As far as future employment is concerned, following the example of other power stations of this type, e.g. in Żarnowiec, it will range from 75-85 people. Today's automation and IT makes this enough people to manage such a facility. At the moment, there is no established timetable for the investment yet, as the work is progressing gradually and is being carried out in such a way, as to prepare for the solutions enshrined in the recently adopted special law on the preparation and realisation of investments in pumped storage power plants and investments. It should be recalled that the investment itself was estimated at around PLN 6.5 billion.

We also asked about sources of funding. The topic of funds for the energy transition was raised in the conversation. The developer of this project was curious to see the current situation regarding these funds. *"We have also approached several foreign infrastructure funds that have expressed interest in cooperating on this investment. We are thinking very seriously about the power market, which is an ideal solution for PSH. The power plant will be able to participate in the energy market and balancing. I count on the fact that system services will finally be marketized".*

Technical parameters and investment difficulties

In an interview with the developer of Tolkmicko PSH project, we also asked about the technical details of this investment. Currently, the largest facility of this type in Poland is the power plant in Żarnowiec. However, comparing the technical parameters of the planned and existing power plant, the Tolkmicko PSH project will allow more than twice as long generation. Żarnowiec PSH can generate electricity in continuous operation for about 4.5 hours, while PSH Tolkmicko, assuming that it is realised with the assumed parameters, will be able to generate electricity for more than 7.5 hours.

Great demand is placed on the water that will be used in the power plant. The salty seawater and the relatively shallow, silted reservoir make this project more complicated on the one hand and extremely interesting on the other. The interviewee acknowledged that the reservoir is shallow, but the large surface area of the reservoir means that will not have problems with water drainage from the lower reservoir, which all power stations in Poland have to deal with: *"This is an additional advantage of this power plant, since the bottleneck of most PSHs in Poland is the bottom reservoir, receiving water, which often has a limitation. These restrictions occur for various reasons, but here they do not exist, due to such a large surface area of the reservoir, so that differences in the mirror will be practically imperceptible".*

On the other hand, the weakness is the salinity. It is not known exactly what the salinity level is and how it will increase after the construction of the canal crossing the spit, how much this salinity will increase compared to what is currently in the Vistula Lagoon.

As a curiosity, we also touched on the visualisation of the development. It depicted the damming, on top water, which was quite an interesting feature. However, the interviewee satisfied our interest: *"Yes, it's interesting. There was an idea, I don't know how feasible it was, to create just an additional damming, using this reservoir and to make a flow once again through a turbine, but I will say frankly that it might be feasible with a reservoir much bigger than the one we are currently talking about".*

It is also worth highlighting that the visualisation of the project shows a floating PV farm. This point was also raised during the interview. *"Yes, this idea is very nice. It is possible to install these floating panels in this artificial upper reservoir, they don't interfere with anything and will generate additional energy. We estimate that this floating photovoltaic power plant could reach a capacity of up to 80 MW. Probably it will be necessary to provide for the possibility of its dismantling during repairs and modernization of the reservoir. However, this can also be dealt with".*

Summary

The concept of building Tolkmicko PSH has caused a big stir in the industry. At the time of the interview with Mr Rusiecki, work was still underway in the Parliament to implement the spec act, but the situation has since changed. A few months ago, the President signed a special law that will facilitate the creation of new PSHs in Poland. However, this document is only valid for one year, so it is quite a challenge for the emergence of new PSH projects.

Sandra Owieczka
Editorial assistant
"Energetyka Wodna" magazine

Michał Lis
Managing editor
"Energetyka Wodna" magazine

The fourth edition of the World Small Hydropower Development Report

The United Nations Industrial Development Organization (UNIDO) and the International Center on Small Hydro Power (ICSHP) published the 2022 edition of the World Small Hydropower Development Report (WSHPDR), available online at www.unido.org/WSHPDR. The WSHPDR is the only global publication dedicated to the dissemination of in-depth information on small hydropower (SHP) development, and serves as a comprehensive reference for decision-makers, stakeholders and potential investors in the SHP sector. In this summary, we look at the major findings and new features included in the latest edition of the WSHPDR.

The WSHPDR 2022 provides a comprehensive overview of the SHP sectors of 166 countries, providing detailed data on their electricity sectors which includes a breakdown of installed electricity capacity and annual generation by energy source, SHP installed capacity and potential as well as recent development in the SHP sector, and overall policy frameworks with regard to renewable energy development. As part of the 2022 edition, the country chapters now also include data on active SHP plants, planned and ongoing SHP projects, policies regulating and incentivizing SHP development, financing opportunities, and estimates of local SHP development costs, where available. Alongside potential barriers to national SHP development, factors enabling growth in the SHP sector are also analyzed.

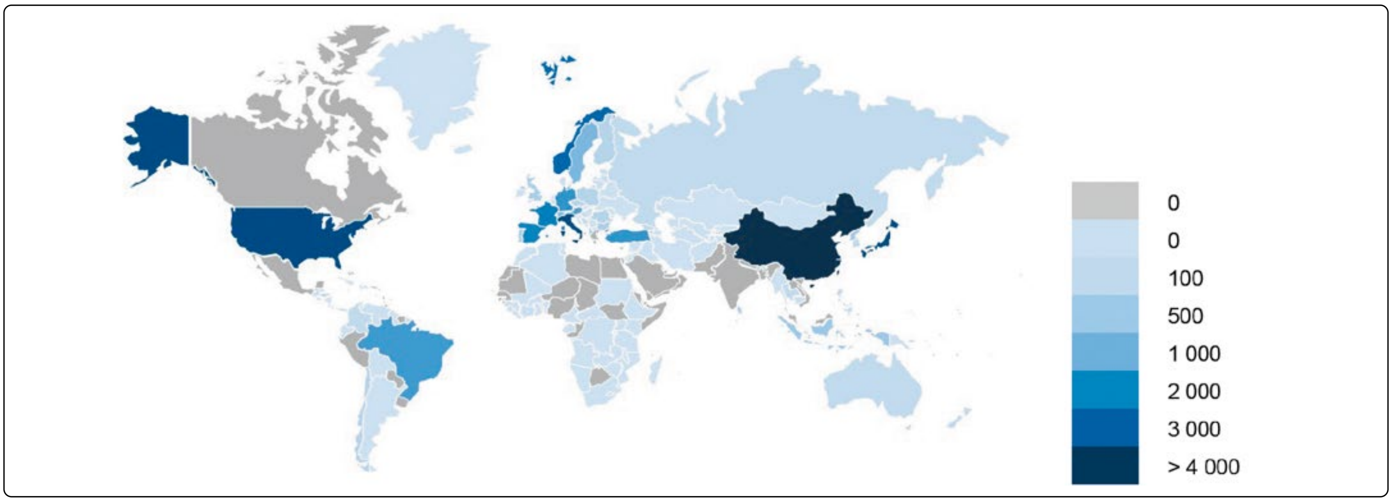
Findings outlined in the country chapters are summarized in 20 regional chapters, and further condensed as part of the report's Global Overview. New additions to the report include three thematic publications highlighting the role of SHP in socio-economic development as well as the impacts of climate change on the SHP sector, and 13 case studies on SHP policy, technological innovations and community benefits. Additionally, the WSHPDR 2022 includes the first-ever Global SHP Database, created through a collaboration of UNIDO, ICSHP, and international experts in the SHP sector, which aims to provide comprehensive, up-to-date, and easily-accessible information on SHP projects across the globe. The database currently includes data from 129 countries and territories across five continents, listing 6,249 existing SHP plants and 8,860 potential and planned plants.

Dynamics of global SHP development

The 2022 edition of the WSHPDR estimates global installed SHP capacity for plants of up 10 MW at approximately 79 GW, accounting for approximately 1 per cent of the total installed generating capacity of the countries surveyed in this report. The total known potential capacity for SHP of up to 10 MW, including both existing plants and prospective sites, is estimated at 221.7 GW, indicating that approximately 64 per cent remains undeveloped. We note that some countries with highly developed SHP sectors have adopted alternative definitions of SHP exceeding the 10 MW threshold and do not report capacity totals for SHP of up to 10 MW separately. Consequently, actual totals are likely higher that both installed and potential capacity figures provided here. An illustration of the global distribution of installed and potential SHP capacities is provided in Figures 1 and 2, respectively.

Relative to the data provided in the WSHPDR 2019, the global installed capacity of SHP of up to 10 MW has increased by 1 per cent, while potential capacity decreased by 3 per cent, reflecting the availability of accurate data on SHP potential. In the case of some countries, SHP potential capacities previously reported in the 2019 edition were based on studies conducted several decades ago, and have been discarded on the recommendation of experts as lacking relevance. In other cases, estimates of potential capacity have been revised downwards, particularly in light of changes to the hydrological regime of some drainage basins as a result of climate change and human activity.

Regional and national trends in SHP development have been very uneven, with rapid growth of the SHP sector in some countries and decline or stagnation in others. On a continental level, increases in installed SHP capacity have been observed across all continents with the exception of Asia, where installed capacity decreased by 1.3 per cent relative to the WSHPDR 2019 (Figure 3). As Asia accounts for the larg-



Source: WSHPDR 2022

Fig. 1. Small Hydropower Installed Capacity of up to 10 MW by Country (MW). *Note*: Highlighted in grey are countries without data on SHP of up to 10 MW or no SHP plants installed.

Source: WSHPDR 2022

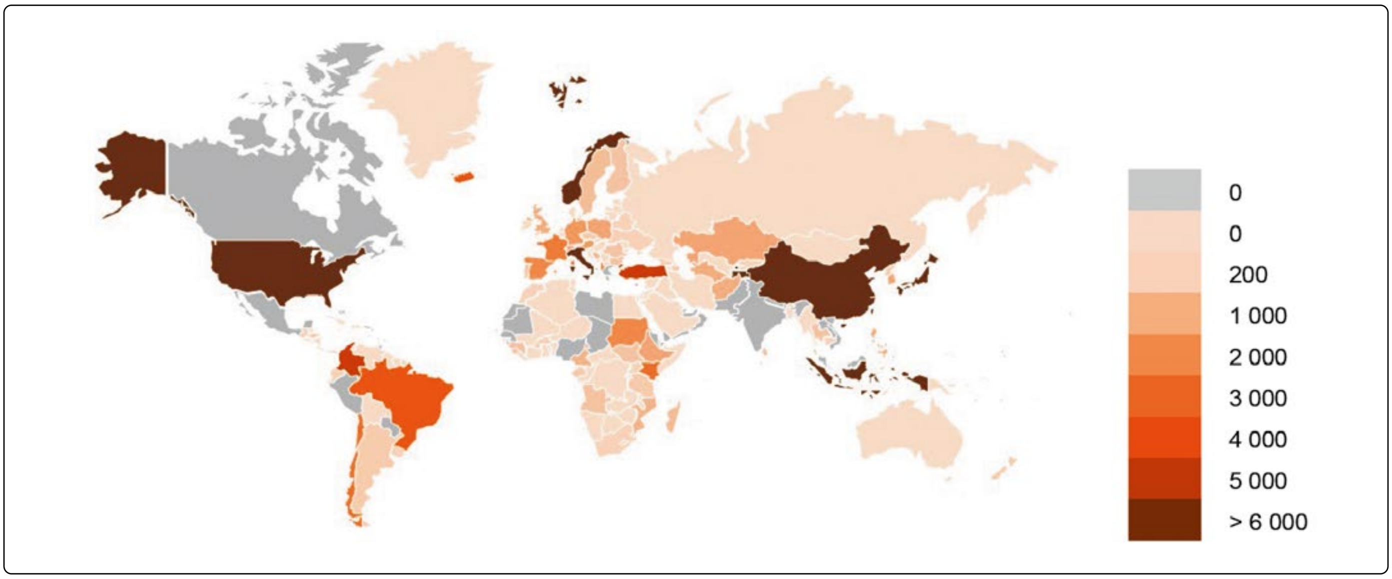


Fig. 2. Small Hydropower Potential Capacity of up to 10 MW by Country (MW). *Note*: Highlighted in grey are countries without data on SHP of up to 10 MW

est share of global SHP capacity (64 per cent of installed capacity and 63 per cent of potential capacity), the net decrease in reported installed SHP capacity in Asia, at 672 MW, has had an outsized impact on the global total. The decrease is explained in part by changes in SHP databases maintained by Turkey, as well as by the lack of data on SHP of up to 10 MW for several countries where such data had previously been available. Changes to reported SHP totals in Asia are therefore more reflective of the availability of accurate data than major expansion or decline of physical assets, although significant real growth of the SHP sector has occurred in several Asian countries, notably China, Georgia, Indonesia and Sri Lanka.

In absolute terms, the largest net increase in installed capacity relative to the WSHPDR 2019 is reported for Europe, at 734 MW, largely accounted for by rapid SHP development in Albania, Italy and Norway. In the Americas, reported SHP capacity increased by 697 MW, mainly due to the inclusion of previously-unreported data on the installed capacity of SHP of up to 10 MW in Brazil. In Africa, total installed SHP capacity increased by 134 MW, and an increase of 13 MW is reported for Oceania. China continues to lead the world in installed SHP capacity, accounting for 53 per cent of global SHP installed capacity, and is followed by the United States of America (USA), Italy, Japan and Norway. Together, these five countries account for almost 71 per cent of the world's total installed capacity of SHP of up to 10 MW. Despite ongoing development in many parts of the world and the reported 3 per cent decrease in identified global potential capacity for SHP up to 10 MW relative to the previous edition of the WSHPDR, nearly two-thirds of the global potential capacity (64 per cent) remains unutilized. In light of newly-available studies, major increases in identified potential capacity for SHP up to 10 MW have been reported for Brazil, Burkina Faso, Guinea, Georgia, Iceland, Indonesia, Sierra Leone, and Sudan. These new data may lead to a positive reassessment of the viability of significant additional SHP development in these countries as well as encourage further investigations of SHP potential in regions where detailed data on potential are lacking.

Source: WSHPDR 2022

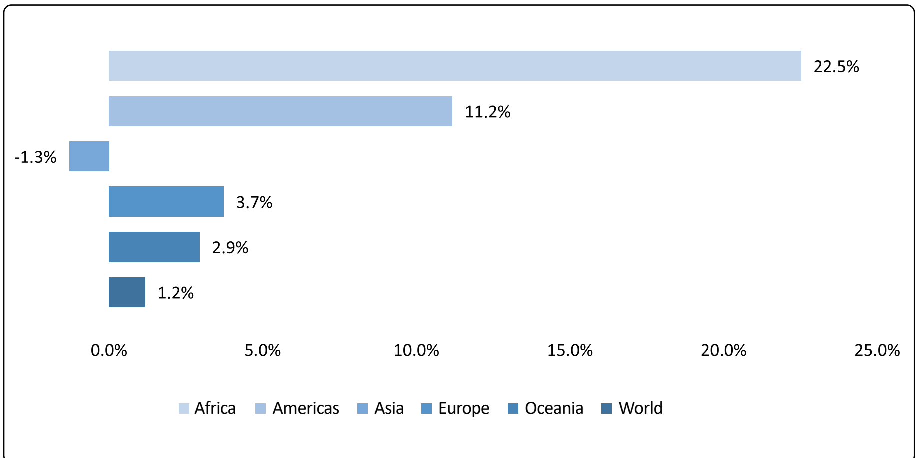


Fig. 3. Change in Installed Small Hydropower Capacity between the WSHPDR 2019 and the WSHPDR 2022 by continent

Factors affecting growth in the global SHP sector

Development of SHP has encountered significant barriers in certain countries and regions, and has in some cases been consequently scaled down or entirely suspended. The most common obstacles encountered by the SHP sector across the world include:

- Some countries and regions have largely exhausted their identified SHP potential. Western Europe has the highest rate of utilization of identified SHP potential, at 83 per cent, due to a long history of SHP development in the region. In other regions, SHP potential is limited by climatic conditions or lack of adequate road access to potential sites.
- Lack of local manufacturing capacity and technical expertise as well as insufficient grid and road connectivity can make SHP projects prohibitively expensive, particularly in remote areas.
- High upfront costs have in many cases reduced the competitiveness of SHP; additionally, sustainable sources of financing are not always available.
- SHP development can be hampered by complicated licensing procedures that may require years of preliminary studies and processing of documentation before construction can commence.
- Incentive programs for RES, including SHP, have proven costly for many gov-

ernments and have been scaled back in some cases, or not implemented in the first place.

- SHP projects increasingly encounter pushback from different social groups, especially in Europe. Resistance to SHP development is frequently environmental in nature, but can also involve commercial entities competing for water use rights.
- The climate crisis has adversely impacted river flow in many parts of the world, decreasing the reliability of generation from run-of-river SHP plants. Additionally, previously-conducted studies of SHP potential in certain regions may no longer reflect the objective reality.

At the same time, substantial opportunities exist across the globe for development of the SHP sector, particularly in light of the fact that 64 per cent of identified SHP potential remains unutilized. Demand for SHP development in many parts of the world is driven by a number of common factors, including the following:

- Decarbonization efforts by governments around the world have led to the adoption of a wide array of policies promoting the development of renewable energy sources (RES). Although feed-in tariffs are being phased out in some countries, alternative forms of support including feed-in premiums, renewable energy auctions, and carbon trading mechanisms are becoming widely available.
- Rising costs of generation from hydrocarbons make renewable energy increasingly attractive to investors even in the absence of legislated incentives, and have been driving renewable energy development in countries with robust incentive programs and also those typically lacking the financial means to subsidize RES.
- Lack of electricity access in remote regions drives demand for off-grid generation capacity provided by SHP.
- Several countries have an assessed SHP potential capacity far in excess of existing domestic demand; in such cases, SHP development represents an opportunity to expand electricity exports to neighbouring countries.
- In countries with little remaining SHP potential or where additional SHP development is inadvisable for environmental reasons, authorities and private developers have increasingly looked at tapping existing non-powered water infrastructure for SHP generation, including aqueducts, water mains, and outflow from industrial sites.
- Sustainability in the SHP sector is also driven by technological innovation. Modernization of existing SHP plants with fish passes, high-efficiency turbines, and smart operational control all reduce impact on wildlife and allow SHP plants to conform to stricter minimal flow requirements. Hydrokinetic systems make SHP development possible in ultra-low-head applications without impounding streamflow.

Thematic publications and case studies

Compared to the previous editions, the WSHPDR 2022 has been expanded with three thematic publications and several case studies aimed at addressing a gap in the understanding of the unique characteristics of SHP technology often ignored in generalized discussions of renewable energy development, in particular those related to the potential of SHP for positive social and environmental impacts. The themes highlighted in the publications and case studies are briefly introduced below:

"SHP and the empowerment of women"

The positive impacts of improvements in electricity access provided by SHP in low-access areas on the daily lives and opportunities for women in these communities and beyond are well-established. These include a reduction of time and labor committed by women to household work due to the use of electric appliances, leading to immediate quality-of-life improvements for women as well as increased opportunities for studying, income generation and other life-enhancing activities. Integrating the gender approach into project design and implementation is critical to ensuring that SHP projects help empower women and girls across the globe, and close gender gaps.

A case study carried out in Brazil noted the high social approval enjoyed by a recently-implemented SHP project in a rural community with low access to electricity. Benefits identified in the study included improved security due to the implementation of street lighting and attendance of night classes by women as a result of increased electricity supply. The study also noted increased use of electric appliances by residents for housekeeping purposes.

Source: Solylend

Photo. 1. John Magiro, founder of Magiro Power (in the middle) with Thomas Poelmans, business advisor (on the left) and Alice Mumbi, operations manager (on the right)

"Prospects for youth in the SHP sector"

Leveraging the creativity and forward-thinking of youth is a crucial part of implementing the energy transition, and the SHP sector can play a leading role in providing opportunities for young people around the world. At the same time, a wide range of barriers exist for young energy professionals who are considering joining or transitioning to the SHP sector, as well as for those already involved in the sector, particularly young women.

A case study from Kenya reviewed the rise of a young hydropower entrepreneur who, just out of secondary school, launched his career in the SHP sector with a simple bicycle dynamo, before scaling up to a 7.5 kW project powering an 8 km mini-grid and eventually founding his own commercially-viable SHP company, Magiro Power. Another case study in Ghana noted the professional opportunities presented to a team of young hydropower engineers through the implementation of a pilot SHP project, allowing them to solidify their earlier theoretical training. These studies highlight the accessibility of the SHP sector but also underline the qualified and structured support required for success of entry-level professionals in the sector.

"SHP and climate change"

SHP has a dual relationship with the climate crisis — it can help mitigate the impacts of climate change by reducing consumption of fossil fuels for electric-

Photo. 2. Community members at the inauguration ceremony of community-run SHP plant in Japan

ity generation, but is also vulnerable to these impacts because of its dependence on the hydrological regime, particularly in the case of run-of-river SHP plants due to their limited capacity for water storage and flood control. Additionally, the impacts of climate change on other sectors, including competing water uses and different requirements from the grid, can cascade to SHP plant operations. The current publication offers a synopsis of projected climate change impacts on SHP by region, provides recommendations on adaptation measures to be considered for climate change-resilient SHP, and indicates the key directions for further research on the topic.

The issue of water shortages was further explored in a case study on environmental aspects of SHP development in Ukraine. The study noted that capacity factors for SHP plants in the country had decreased from 44 per cent to 20 per cent between 2013 and 2020, suggesting climate-change induced reductions in streamflow as the chief cause. The study highlighted examples of two recent SHP projects implemented on outflow from wastewater treatment facilities as environmentally-sustainable alternatives to run-of-river SHP.

Additional case studies included in the WSHPDR 2022 topics investigated the role of SHP in community development, innovative SHP technologies, incentive policies for SHP, and integration of robust environmental sustainability principles into SHP project development and operation. These included:

- A community – developed and managed SHP plant in rural Japan;
- Retrofitting of existing water infrastructure with SHP turbines in Italy;
- Intelligent operation control and dispatching systems for complementary power plants in China;
- A historical overview of SHP development and incentive policy in Tajikistan.

Conclusion

The latest edition of the WSHPDR highlighted recent trends in SHP development, assessment and integration with broader social, economic and environmental goals. While global SHP capacity has continued to increase, much of the identified global potential remains untapped. Further development of SHP is challenged by climate change and human activity that have reduced available potential in some regions, and a range of emerging obstacles including stricter environmental requirements, reduction in financing and incentives, and social resistance complicate the implementation of new SHP projects. At the same time, SHP development is favored by a growing global push towards decarbonization, rising costs of generation from fossil fuels, and new methods of assessment that have identified previously – overlooked SHP potential, among other factors. SHP is likewise finding increasing recognition as a vehicle for positive socio-economic change, while emerging SHP technologies can help minimize environmental impacts and make new development both sustainable and cost-effective.

Relative to the previous editions of the WSHPDR, the 2022 edition represents a qualitative improvement in assessing the current status, dynamics, and role of the global SHP sector. In particular, the inclusion of a Global SHP database provides an important baseline for detailed future assessments of SHP capacity and potential across countries and regions, allowing for a detailed comparison of dynamics in the sector on a project-by-project basis. Additionally, an effort has been made to provide policy-makers, investors and other stakeholders with the latest data on national legislation, regulations, financing, and costs pertaining to SHP development, as well as to meaningfully assess the social and economic impact of SHP technology and examine practical applications that transcend the goals of power sector development.

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THV mini-turbines for energy recovery in pumped systems and grid control

In this paper, constructional solutions for THV miniturbines for the management of watercourses with low energy potential and which can operate as regulators in systems where pressure reduction is necessary for technological reasons are presented. The energy parameters of miniturbines were compared depending on the design and the influence of the applied flow system on the efficiency and control range was analysed.

The presented research results are part of the work carried out at Hydro-Vacuum S.A. within the project entitled 'Research work on the development of an integrated innovative design of miniturbines and standard pumps'. The project is co-financed by European Funds under the Operational Programme Intelligent Development – competition: Fast Track. The aim of the project is to develop and implement an integrated series of innovative pumps and miniturbines based on common – mass-produced components. This is to ensure high availability of the miniturbines and their relatively low price, compared to individually designed and manufactured turbines. The project includes the development of a new, high-performance series of twelve pumps and miniturbines with specially designed Francis-type impellers and blades with the following parameters in turbine operation: Q flow rate of 100 to 1,000 m³/h (0.0278–0.278 m³/s) and H head of 10 to 60 m.

Rising electricity prices and the need to meet imposed climate targets are forcing an extensive analysis of liquids transport systems and an assessment of whether energy is being lost through pressure throttling or idle liquid discharges. An excellent example of such systems are process systems for cooling water in industrial plants with a central pumping station supplying consumers with different hydraulic resistances. They can also be water supply or district heating networks where, due to the terrain or the proximity of the central pumping station to the consumer, regulators are required to reduce the pressure to a certain value.

Fig. 1. Miniturbine THVf.150-250 – flow system of the Francis turbine factory installed in the body of the series-produced NHVf.150-250 pump

In the above systems, without the need to build costly hydroelectric infrastructure, as is the case in classic hydropower, there is a fairly high ease of recovering lost hydraulic energy. Due to the relatively low energy losses of a few to several (sometimes tens of) kilowatts, the development of such 'sources' is economically justifiable only for low investment costs. Assessing these quickly is difficult, particularly as water turbines are usually designed for dedicated locations for individual hydraulic parameters and for flow rates well in excess of those encountered in the systems described above (tens to hundreds of m³/h).

Energy recovery machines for comparatively low-flow system

Recently, there has been increasing interest in the use of turbine-driven pumps. It is good solution for systems for which it is not cost-effective to design dedicated water turbines or due to operating parameters such as temperature or chemical composition. Some problem with their application is the imperfect mathematical models for calculating actual operating parameters, including efficiency. In most situations, there is a lack of widely available real-world energy characteristics of pump operation in turbine motion. It is true that there are at least several algorithms for determining the performance of pumps in turbine motion. However, they give divergent results and, based on the authors' research, fail in particular for small-sized pumps with narrow impeller flow channels. In view of the above, in 2021, Hydro-Vacuum S.A. in Grudziądz began work on the construction of a series of mini-turbines with a flow rate of 100 to 1,000 m³/h, for the production of which structural elements of newly designed pumps are used, dimensionally compliant with PN-EN 733 (diameters of connection stubs: DN125, DN150 and DN200). The basic assumption of the project is to use series-produced pump bodies and drives and to incorporate specially designed turbine flow systems. This approach is intended to ensure a relatively low manufacturing cost of the machine. The design and bench testing of a family of twelve miniturbines is intended to enable an easy and quick selection of a design solution for the given operating parameters and to guarantee a high degree of certainty of achieving the required efficiency.

Carried out research work

The mini-turbine project is carried out jointly with the Department of Energy Conversion Engineering, Fac-

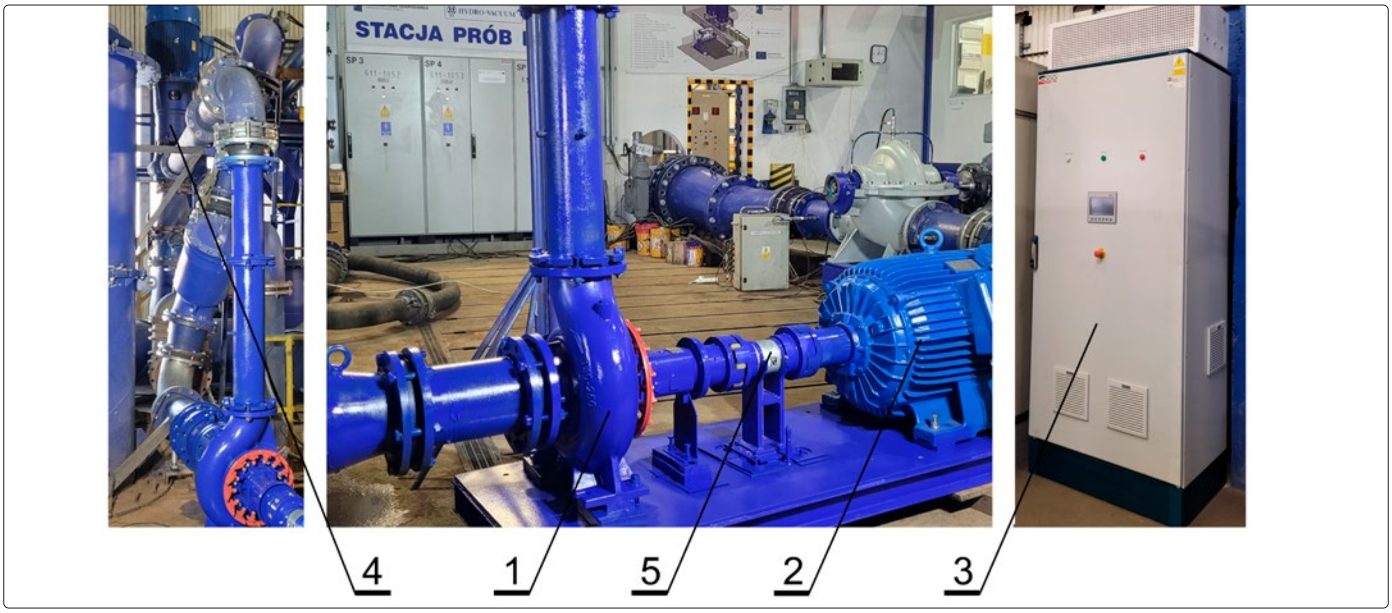

Fig. 2. Test stand for determining energy parameters of mini-turbines and pumps in turbine motion (1 – turbine/pump under test, 2 – PM synchronous generator, 3 – cabinet with energy return module to the grid, 4 – feed pump, 5 – torque meter)

ulty of Mechanical and Power Engineering, Wrocław University of Technology. In order to determine the actual operating parameters of the miniturbines (1) and pumps in turbine motion, a test rig (Fig. 2) was constructed at the Hydro-Vacuum S.A. Test Station in Grudziądz, equipped with:

- a synchronous permanent magnet generator (2) type: PMwg315-6 with a nominal power of 120 kW and a maximum speed of 1800 per minute,
- a control cabinet (3) fitted with an energy recovery converter of the type: EW-400V-132 kW,
- feed pump (4) type FZP.7.20 with a power of 132 kW and maximum capacity of 1,000 m^3/h.

Hydraulic parameters are measured with standard measuring devices, with which the Test Station is equipped (pressure transducers type: PC-28 and electromagnetic flow meter type: MAG 5100 W), and to determine the power on the turbine shaft, two torque meters (5) type: MT with a range of up to 1,500 Nm and 200 Nm were used.

The miniturbines are tested in a closed circuit in a horizontal position with an outlet pressure of ~0.6 bars. Based on the results of the measurements, the characteristics of the slope H(Q), the generated shaft power Pw(Q) and the efficiency η(Q) as a function of the gullet are determined. Measurements are carried out for the operation of the turbine set at variable speed with values: 770, 920, 1,020, 1,220, (1,520) per minute and/or varying the blade angle settings of the miniturbine under test. Miniturbine designs were carried out in two ways. For miniturbines with inlet guide vanes, adaptation of Francis turbine design algorithms to the size of the designed machines and low flows was carried out. For mini-turbines without inlet guide vanes, analyses were conducted on the possibility of improving efficiency and increasing power by modifying design algorithms and rotor shapes for centrifugal pumps. Analyses were conducted through one-dimensional flow theory calculations to determine the parameters of the 2D model, and then a parameterised 3D model was built. In order to diagnose and eliminate local energy dissipation in the newly designed miniturbine flow elements, the virtual 3D models were checked by performing numerical flow simulations using the commercial calculation code Ansys CFD Ultimate. The highest-scoring flow systems were fabricated using FDM incremental manufacturing technology and tested on a test bench. The overarching goal of the project was to achieve energy efficiency values higher than those tested for a pump in turbine motion and to increase the generated power in a machine of a given size.

THV miniturbine construction types and recommended applications

As part of the research work carried out, three miniturbine design solutions were developed:

- **THV** – mini-turbine without inlet guide vanes with specially shaped multi-bladed impeller,
- **THVf** – mini-turbine with inlet guide vanes with externally adjustable blade angle and impeller design based on Francis type water turbine,
- **THVfc** – mini-turbine with inlet guide vane of fixed blade angle and impeller of Francis-type water turbine design.

THV mini-turbines (Figure 3) are differentiated from turbine motion pumps by the type of impellers used (2). The modifications relate to the number and shape of the blades and the meridional cross-section, the modification of which is intended to facilitate the inflow of fluid from the volute into the intervolute channel and to increase the reduction in the speed of the fluid leaving the impeller. The THV design, due to its low complexity, is recommended for use in systems with high fluid temperatures (up to 140°C), high chemical aggressiveness and abrasive properties.

The THVf miniturbines (Fig. 4) are designed for systems where a wide range of flow control is required. The pump body (1) incorporates stay rings (2) in which the wicket gate (3) are embedded to direct the fluid into a Francis-type impeller (4). Vane angle adjustment is possible from outside the machine via the gate operation ring (5). It should be noted that, although similar in design to classical Francis turbines, this system, due to its small size, does not allow for complete shutdown of the liquid inlet to the of the impeller by changing the setting of the gate. Miniturbines of this type are recommended for cold water systems (up to 60°C).

The THVfc miniturbines (Fig. 5) replicate the flow arrangement of the THVf mini-turbines, with the difference that the stay vanes (2) is made as a monolith with a preset blade angle without the possibility of infinite adjustment. This design, like that of the THV, is recommended for operation in systems with high medium temperatures (up to 140°C) and high chemical aggressiveness, due to its low complexity. The chemical and abrasion resistance of the above designs depends on the materials used to build the machine components. Bodies and rotors are made using casting technology, therefore the basic materials for bodies are grey cast iron, ductile cast iron, carbon steel and acid-resistant steel. Rotors for THV are made of: grey cast iron, carbon cast steel, acid-resistant cast steel and bronze, while THVf and THVfc rotors are made of bronze.

Energy performance and regulation range

As a result of the special design of the flow system, the developed mini-turbines are characterised by high energy efficiency with nominal values of 80 to 84%. In the example shown in Fig. 6, the energy

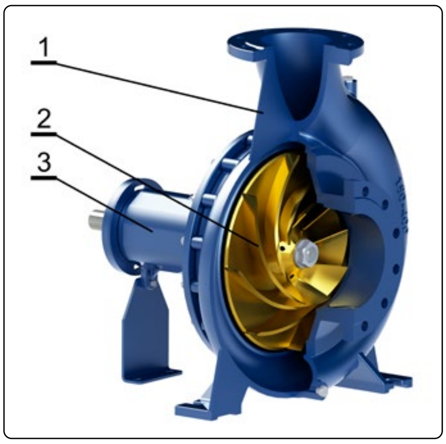

Fig. 3. Miniturbine THV (1 – pump casing acc. to EN 733, 2 – Mini-turbine runner, 3 – standard bearing housing)

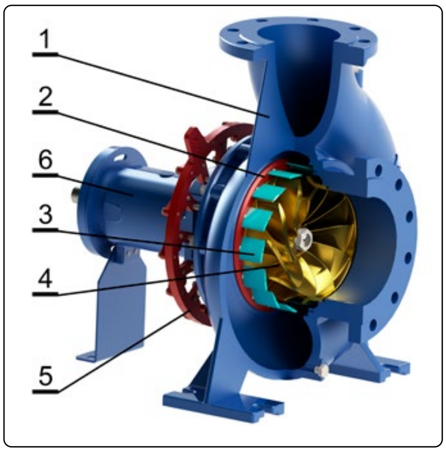

Fig. 4. Miniturbine THVf (1 – pump casing acc. to EN 733, 2 – stay ring, 3 – wicket gate, 4 – Francis runner, 5 – Gate operation ring, 6 – standard bearings housing)

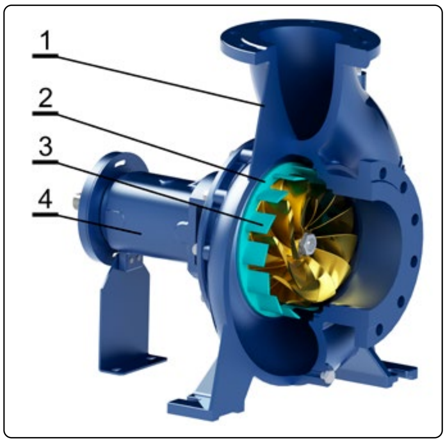

Fig. 5. Miniturbine THVfc (1 – pump casing to PN-EN Standard 733, 2 – stay vanes , 3 – Francis runner, 4 – standard bearing housing)

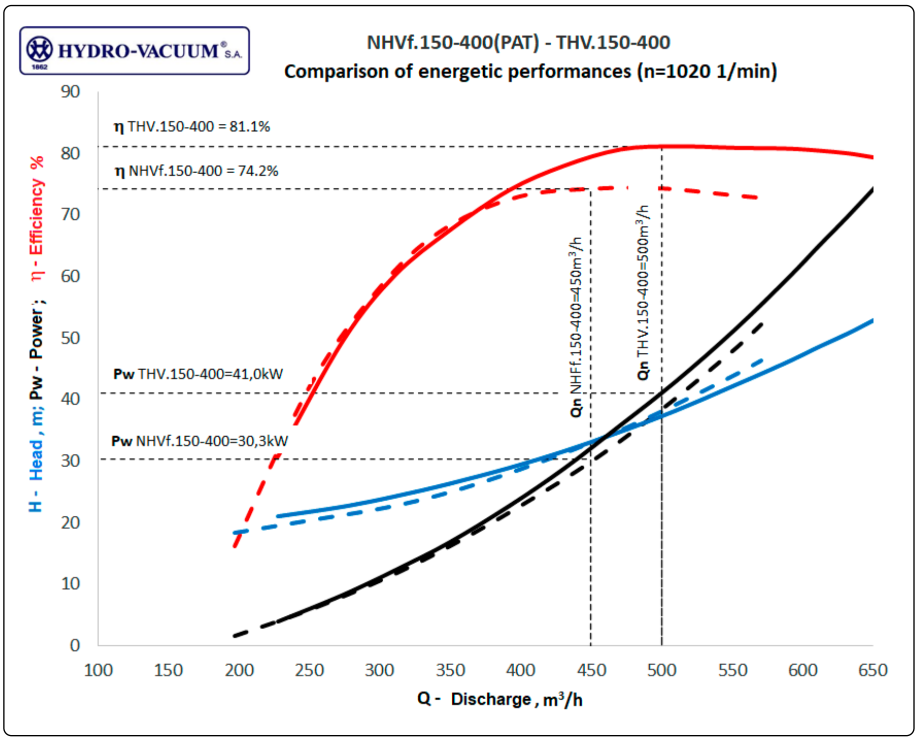

Fig. 6. Comparison of the energy performance of the THV.150-400 mini-turbine (solid lines) and the NHVf.150-400 pump in turbine motion (dashed lines) for n=1020 per min.

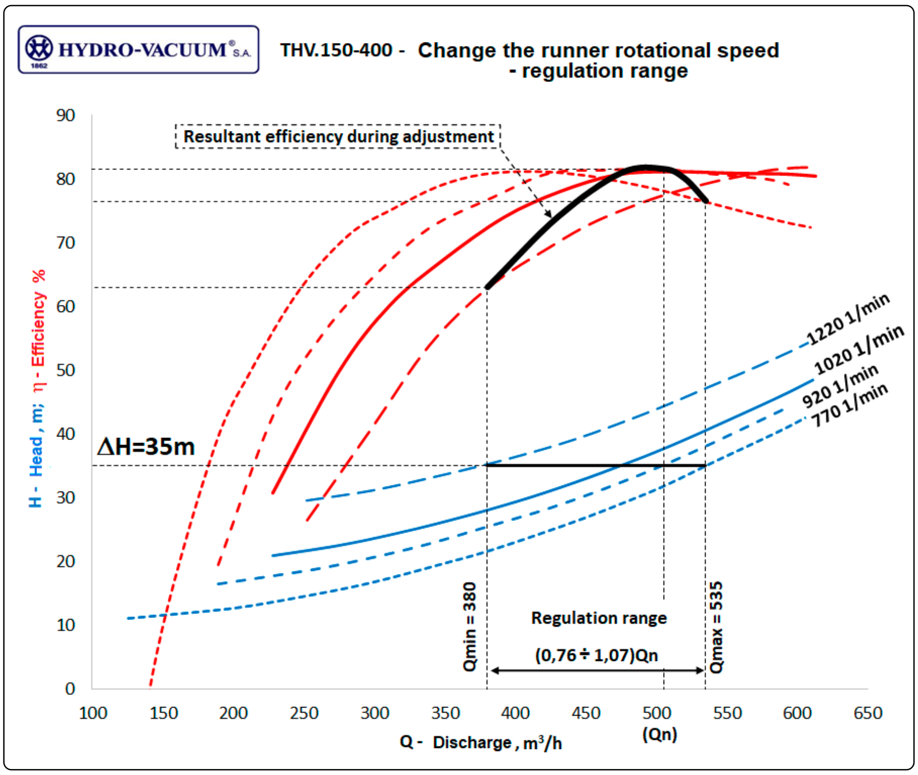

Fig. 7. Comparison of the energy performance of the THV.150-400 mini-turbine during speed control during constant pitch operation

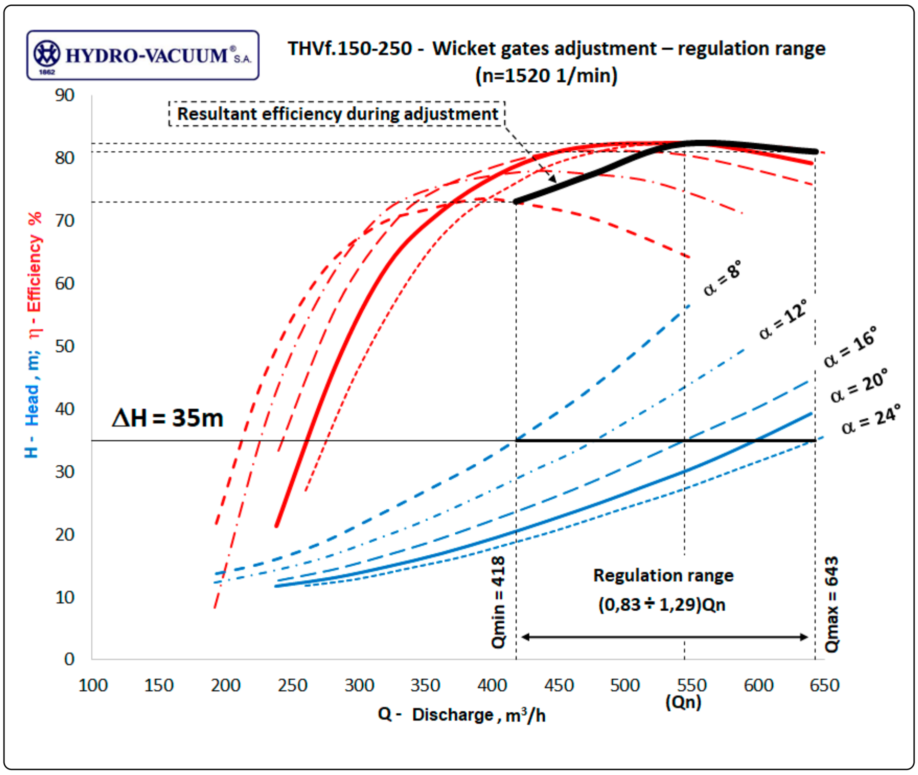

Fig. 8. Comparison of the energy performance of a THVf.150-250 mini-turbine during blade angle adjustment (n = 1520 1/min) during constant pitch operation

characteristics of the NHVf.150-400 pump (dashed lines) in turbine motion (PAT) and the THV.150-400 mini-turbine built on its basis (solid lines) are placed. By using the new multi-vane rotor design, a significant (more than 6%) increase in the efficiency of the miniturbine with respect to the pump (PAT) was achieved. The optimum gullet of the machine has also increased, which allows the miniturbine to be used at higher parameters while maintaining a high efficiency than for the PAT, at the same production cost. The shape of the characteristics of efficiency η(Q), slope H(Q) and power Pw(Q) of the two machines is strongly similar. A favourable flattening of the characteristics is observed for H(Q), which extends the control range by varying the speed during operation to a constant slope.

The THV and THVfc mini-turbines are designed for constant-speed operation. The control range can be extended by equipping the system with a frequency converter for variable speed operation. In the example shown in Fig. 7, the THV.150-400 mini-turbine is illustrated in a system where a throttling of 35m is required. By varying the speed from 770 to 1,220 per minute an operating range of 380 to 535 m³/h was obtained, which corresponds to a value of 31% of the nominal throughput (Qn) of the miniturbine. The efficiency in this range starts from 63% for the lowest flow rate, through 81.1% for the nominal parameters and 76.5% for the maximum overshoot. The graphical distribution of the resultant efficiency during speed control is illustrated by the black curve in Fig. 7. The rather unfavourable phenomenon of reduced efficiency for flows deviating from nominal is noted.

The use of a continuously variable blade angle in THVf turbines makes it possible to achieve a much wider range of regulated operation than in THV and THVfc. For an analogous case as above, a THVf.150-250 mini-turbine was selected with a smaller footprint than the THV.150-400, but operating at a higher nominal speed (n=1,520/min). For a head of 35 m, the control range is from 418 to 643 m³/h, corresponding to a value of 46% Qn. In addition, significantly higher efficiencies are obtained starting from 73% for the lowest flow rate, through to 82.3 for the nominal parameters and 81% for the maximum flow rate. The steepness of the resultant efficiency curve illustrated by the black line in Fig. 8 is considerably less than for the THV.150-400, which, combined with the wider control range, offers the potential for greater energy production.

Summary

Miniturbines built using mass-produced pump components are a good cost alternative to individually designed and manufactured water turbines. They can be used to recover energy lost in pumping systems and to develop watercourses with low potential. The use of specially developed turbine systems ensures high energy production efficiency and allows operation over a wide flow range. The availability of the machines in a wide range of materials and for high medium temperatures also enables their use in process systems of industrial installations.

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Photos and graphics come from the archive of **Hydro-Vacuum S.A.**

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Pumped storage power plants in Poland – overview

In Poland, nearly 70% of electricity is currently generated in thermal power plants fueled by coal or lignite. The transition from these sources of electricity to Renevable Energy Sources (RES) will not be a straightforward action, requiring large investments and financial expenditures, for large-scale energy storage facilities such as pumped storage power plants. In the past months, there has been increasing disscussion of the need to build more facilities of this type. Therefore, it is worth refreshing our knowledge of the principle of Pumped Storage Plants (PSP) and their function in the energy system and reviewing the existing facilities in Poland.

At present in the world there are about 2,500 large thermal power plants, which use coal or lignite as the basic fuel. In Poland nearly 70% of electric energy is produced in this type power plants. Operation of these plants is in a contradiction to sustainable development and limitation of the emission of greenhouse gasses. This situation should change rapidly, because in other situation it might result in climatic disaster. The last energy analyses indicate, that potential resources of wind and solar (photovoltaic) energy would be sufficient for the whole present and future world economy and society. The problem is, however, that both these sources are not stable. The wind is not always blowing and at night the photovoltaic cells do not produce electricity because the sun is not shining. The basic problem is not production of electric energy, but it's transmission and storage, when it is in abundance and subsequently make it accessible, when it is needed. The problem on a slightly lower scale is with nuclear power plants, which work efficiently at constant load. This creates the problem of storing excess electricity generated when it is not needed. This is an additional problem that Poland will soon face when engaging in the construction of large nuclear power plants.

Storage of electric energy is a very difficult and complicated problem. Storage of electricity is now accomplished by means of pumped storage hydraulic power plants (PSP). This solution passed a long way by improvements and modernization. Now PSP are often utilizing existing standard hydraulic projects, which survive now some kind of renaissance

The way from conventional hydraulic power plant to the pumped storage power plant

From the early days humans used the water energy for various purposes. These were various types of mills, water forges or sawmills. Their energy, however, could be used only on the spot where it was generated. These were grain mills, wood miles or smithies. The most widespread devices for the use of water energy were water wheels of various kinds. These devices can be called hydraulic plants, as the water energy could only be used at the place where it was generated, without possibility to transmit it to further distances.

At the end of XIX century there was important change in hydraulic, electric energy. In 1891 the first hydraulic power plant on the Rhine River was put into operation. In 1895 the first power plant was constructed on the Niagara River. In these facilities mechanical energy was transferred into electric energy and it was possible to send it to places where it was needed. It was revolution in energetics.

In the early days of hydroelectric power plants, it became apparent that even the small amount of electricity generated could not find a market. This was the case with the Żur and Gródek power stations built in Pomerania Voivodeship in the 1930s, with a total capacity of 13 MW. A similar example is the cascade of hydroelectric power stations on the Radunia River, with a total capacity of 16 MW from 8 power stations, which was then sufficient to cover the electricity needs of the city of Gdansk. Hydropower plants have the basic advantage that they can be very easily started up as well as regulating the power associated with the current demand. Moreover, water turbines and generators are very efficient machines and do not pollute the environment. There were thousands of such devices in Poland after the II World War, which were connected to small watercourses and reservoirs that collected water for use.

In Europe and the USA, new dams and weirs for hydropower utilising technically and economically favourable locations were rapidly built. However, these investments were very expensive and required long lead times. The world does not accepta vacuum and thermal power plants powered by steam turbines of large capacities of several hundred or even thousands of megawatts began to be built rapidly. This led to the development of the coal mining sector and its transport from the mining site to the power station. These were hundreds or even thousands of tonnes per day.

In parallel, the first nuclear power plants were built, in which the previous heat source (coal-fired boiler) was replaced by a nuclear reactor. The advantage of nuclear power plants was that they avoided the costly extraction and transport of coal as well as atmospheric pollution by the greenhouse gas carbon dioxide. However, the drawbacks of these power plants were the radiation hazard in the event of an accident, the supply of nuclear fuel as well as the storage of utilized nuclear fuel elements. Both of these power plants, classic thermal and nuclear, despite their many advantages, have one negative thing in common. They are difficult to regulate power quickly, depending on demand.

In the economy and society, there was an uneven demand for energy throughout the day. There was a morning peak and an evening peak. This is where hydroelectric power began to come into deficiency. Initially, this was a peak operation with partial storage of water in the upper reservoirs from lower reservoirs. To improve these situations, pumped storage power plants began to be developed. In Poland, the Porąbka-Żar PSP, Żarnowiec PSP and Żydowo PSP were constructed.

Over time, it became apparent that there was an equalisation of electricity demand throughout the day and even on all days of the week. As a result, the role of ESPs gradually began to be unnecessary and the planned power stations were temporarily suspended. This was the situation of the proposed PSP Młoty in Poland.

In recent years, the whole world has come to understand that the current generation of electricity by burning coal, oil or natural gas is rapidly leading humanity to extinction in the form of radical climate change. It has been realised that the future of humanity's electricity supply is in renewable energy sources (RES). These two primary sources are wind and photovoltaic electricity. Unfortunately, both of these sources are completely uncontrollable and out of real electricity demand. The problem is energy transmission and storage.

The principle of the operation of pumped storage power plant and their development

Pumped storage power plants are well known and have been in operation for many years around the world. Pumped storage power plant (PSP) is not a typical power plant. It does not produce electric energy, but stores it during the period of its abundance and provides it during period of requirement. The use of the term power station in this case is somewhat of an abuse, as this power station does not generate energy, but merely converts energy. These facilities operate with very high efficiency (70–80%), which indicates amount of energy used for pumping and subsequently regained during turbine work. (PSP) consists of two reservoirs with water level on different altitudes and conduits connecting these reservoirs, and the power plant with reversible units.

The PSP consists of two water reservoirs whose water table is at different levels (Fig. 1). he difference of water level in both reservoirs is the head measured in meters. Reservoirs are connected in a permanent way (open channel, conduits, shaft) enabling water flow in both directions. The lower reservoir is in general natural reservoir: lake, lagoon, bay, or river. Upper reservoir is in general artificial. The volume of the upper reservoir is usually limited and shows the magnitude of energy stored in water of the reservoir at the potential head. During the operation of PSP the head changes due to the filling of both reservoirs.

There usually do not appear water losses, only small losses for evaporation. They are advantageous, because Poland has a modest surface water resources. The pump cycle begins with the inflow of water from the reservoir to the pump-turbine unit. Due to the operation of the pomp by the energy from energy system water is discharged to the upper reservoir (Fig.1. dark green arrow). Stored in the reservoir water presents amount of potential energy. When energy requirement appears water flows from the upper reservoir through the turbine thus producing electric energy, which is sent to the network.

Storage of water in reservoirs at classic hydraulic power plants

Hydropower plants have a very important advantage – they can operate with large efficiency at changing heads and discharges, differing from installed parameters. This allows to decrease the power of hydraulic power plant when such power is not necessary. This requires the decrease of discharge through the power plant and store water in the reservoir upstream of the dam or weir. This results in the increase of water levels in the reservoir. If this are short time changes they do not result in protests of ecologists. When these changes are longer (weekly or even seasonal) they cause protests not only ecologists, but also social, because these reservoirs are often utilized for recreation purposes. Changes in discharge through the dam result in river downstream from the dam additional, detrimental morphological changes in river bed caused by siltation. Reservoirs in which the same amount of water which flows into the reservoirnflows out either through spillways or turbines are called once-throug reservoirs.

Hydrpower plants with upper reservoirs and compensation reservoirs

Construction of high dams with large upper reservoirs created advantageous conditions to form hydraulic power plants with high discharges, which very often exceeded average flows of these rivers. Solution of these problems was solved by means of compensation reservoirs. In these reservoirs water was collected from picking power operation of the plants and then released gradually to the river downstream with smaller discharge. These type facilities in Poland are: Rożnów with compensation reservoirs Czchów on the Dunajec River and Czorsztyn-Niedzica on the Dunajec River with compensation reservoir Sromowce Wyżne on the Dunajec River, Solina on the San River with compensation reservoir Myczkowce and Porąbka dam with compensation reservoir Czaniec.

Hydraulic power plants with compensation reservoirs and reversible units

Formation of compensation reservoirs downstream of large dams and power plants to equalize the discharge downstream in the river created the possibility to utilize equilibrium reservoir as the lower reservoir of the pumped storage power plant. It was only necessary that the installed turbines are reversible and can be used as pumps. This way water

Source: Author's archive

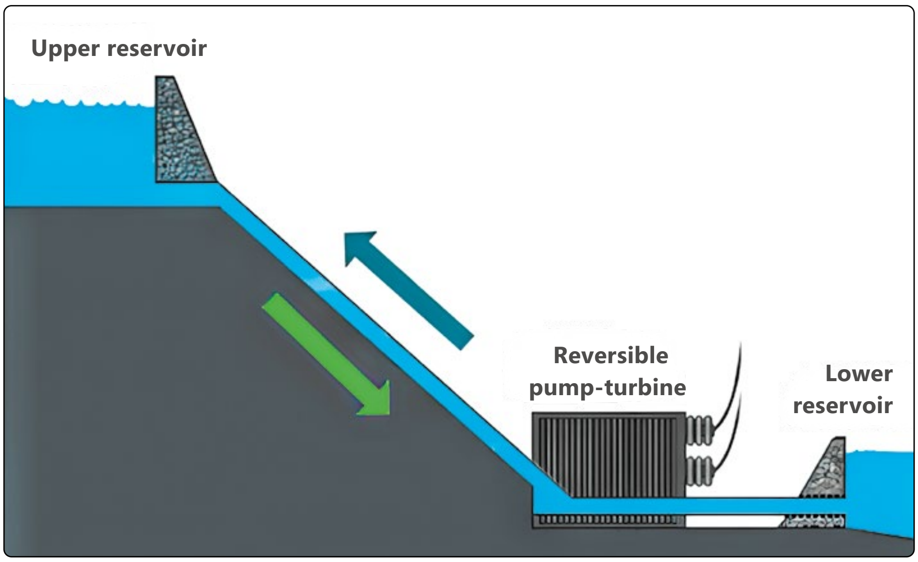

Fig. 1. Operation scheme of PSP

which was discharged through the turbines during picking operation to compensation reservoir could be discharged back to the upper reservoir. It is very advantageous solution from energy point of view. In Poland we have two such projects. These are: Solina with compensation reservoir Myczkowce on the San River and Corsztyn-Niedzica on the Dunajec River with the compensation reservoir Sromowce Wyżne.

Pumped storage power plants in Poland

Poland has 6 PSP including 3 with classic reversible units. The oldest is PSP Dychów constructed in 1933–1936 and totally modernized in 2021. The remaining are: Żarnowiec, Porąbka-Żar, Żydowo, Czorsztyn-Niedzica and Solina. Total installed power in these PSP is at present 1.8 GW.

Source: Lech Adamczewski

Fig. 2. The view of PSP Żarnowiec, conduits, and the upper reservoir

Pumped storage power plant Żarnowiec

Construction of pumped storage power plant began in 1973 and it was commissioned in 1982. In the same year started the construction of nuclear power plant (NPP), which was considered as important energy unit. NPP was situated at the shore of the lake and was intended to use the lake as cooling water reservoir. NPP was designed to consist of 4 reactors of the total power 1,600 MW. The reactors were to be of Czech production (Škoda) under licence from the Soviet Union. The turbines were to be made by ZAMECH Elbląg and the generators by DOLMEL Wrocław. 70 Polish companies were involved in the construction of the NPP. In 1989 the government undertook the decision to close the construction because of a very unfavorable social and political situation for nuclear energy. It is estimated that at the moment of closing the construction it was completed in about 60%.

PSP is situated in Pomorskie voivodship. The owner of the powerplant is the PGE Energia Odnawialna. The project consists of Żarnowiec Lake which forms the lower reservoir. The volume of the lake at water elevation 2.00 m a.s.l. is 106 million m^3 and a surface area of 135 ha. The water elevations due to pump-storage power operation range within 1.00 m. The lake with the powerplant connects trapezoidal open surface canal 850 m long and at bottom widths 100 m.

The power plant consists of 4 vertical reversible units Francis type and the power in turbine cycle is 716 MW. In the pump cycle the power plant needs the power of 800 MW. The power plant is connected with upper reservoir by means of 4 conduits of the lengths 1,100 m (Fig. 2). The diameters of the conduits change along the length from 7.1 to 5.4 m

The upper reservoir is on the moraine hills in the location of previous village Kolkowo. The reservoir is lined with asphalt layer and has the volume of 13.8 mln m^3. The maximum water elevation in the upper reservoir is 126 m a.s.l. The head of the power plant changes from 108 to 126 m. The water level fluctuation in the upper reservoir is 16.5m. The maximum discharge in turbine cycle amounts to 700 m^3/s. The filling of the upper reservoir lasts 6.5 hours. Fully filled reservoir includes 3.6 GWh energy and its efficiency achieves 73%.

Source: ENERGA SA

Fig. 3. The view of the power plant Żydowo, pipelines, and open channel

Pumped storage power plant Żydowo

The first information about the possibility to construct pumped storage power plant Żydowo come from the 30-is of XX century. The firm Siemens was interested in this project. This power plant was constructed in 1964–1971. Power plant is located in Zachodniopomorskie voivodship. The owner of the plant is holding Energa. The project consists of two natural lakes located near each other, which have important difference in water levels. The Lake Kamienne, which forms upper reservoir has the surface area about 100 ha and average depth 6.4 m. The average water surface is at the elevation 160 m a.s.l. The storage power capacity of the upper reservoir amounts to about 0.7 GWh.

Lake Kwiecko (lower reservoir) has the surface area 140 ha and average depth 4.0 m. Water surface is at the elevation 80 m a.s.l. The lakes are connected by means of an open channel of the length 1,316 m of trapezoidal cross-section and the width 12 m. 3 steel pipelines have the length 467 m and diameter 5.0 m (Fig. 3).

Power plant is equipped with two pomp-turbines, and one classic unit of Francis type. Total discharge in turbine cycle is 240 m^3/s which provides the power 176 MW.

Source: Bobowice Municipal Office, images for the Dychów pumped storage power plant

Fig. 4. The view of the upper reservoir, power plant Dychów and the Bóbr river

Pumped storage power plant Dychów

Pumped storage power plant Dychów is in the voivodeship Dolnosląskie at the Bóbr River. It is the oldest hydraulic power plant in Poland constructed in 1933–1936 by the enterprise Voith Siemens. This power station supplied electricity to Berlin (Fig. 4). The upper reservoir (Dychowskie Lake) has the area of 1 km^2 and total volume 4 mln m^3. The replenishment of the water in this reservoir is a 20.4 km long derivation canal. from the Krzywaniec weir on the Bóbr River. At present power plant consists of 3 Kaplan turbines of the power 30 MW each. Recently power plant has undergone important modernization, which lasted 3 years. The power station is capable of delivering 17 MW for 5 hours. The energy capacity of the upper reservoir is 0.22 GWh.

Source: wikipedia.org/Ongrys

Fig. 5. The view of the upper reservoir of pumped storage power plant Porąbka-Żar

Pumped storage power plant Porąbka-Żar

The idea of the development of hydraulic pumped storage power plant was already known before I WW. Project is in Śląsk voivodeship near Żywiec. Power plant is the only one underground plant in Poland and uses Lake Międzybrodzkie as the lower reservoir. This lake of the lengths 5 km has mainly flood character and was formed by the construction of the dam Porąbka. It has the volume 26.6 million m³. The first project was formed in 1969 and the construction began in 1970. The main parts of the project were completed in 1974–1979. The first of the 4 units began operation in 1979. The lower reservoir has now recreational character and presents good fish supply.

Upper reservoir is artificial (Fig. 5) of oval shape is located on a hill. It has asphalt lining and dimensions 650 m (lengths) and 250 m (widths) and maximum volume 2.3 million m³. Reservoir is surrounded by a dyke of the height 30 m. The maximum discharge from the reservoir during turbine cycle is 4 x 36 m³/s. The only one outflow shaft with a length of 500 m of circular cross-section has the diameter 6 m and is equipped in surge tank to mitigate pressure differences due to changes in discharge. The upper reservoir has the energy volume of 2.0 GWh.

The power plant is equipped with 4 reversible Francis units of vertical axis. In turbine cycle power amounts to 125 MW and in pump cycle 135.5 MW. To put into operation in turbine cycle power plant needs 3 minutes, while in pump cycle about 10 min. The turbines were manufactured by the enterprise BoVing from England. The outflow tunnel has a diameter of 6 m and a length of approximately 500 m. The voltage rating of the generators is 13.8 kV. Power is fed out of the generator via screened electrical buses to an oil-filled block transformer, increasing the voltage level to 242 kV. The power is then fed into the overhead line via switchyard and fed into the national electricity system.

Source: Kacper Kowalski/PGE Energia Odnawialna

Fig. 6. The View of Solina Dam, upper reservoir, pumped storage power plant and lower reservoir Myczkowce

Pumped storage power plant Solina with compensation reservoir Myczkowce

The idea of the construction of the dam Solina on the San River is known since 1921 and returned in 1936–1937. New design was completed in 1955 as the new design of the dam and power peaking power plant with the compensation reservoir. Construction started in 1960 and was completed in 1968.

The dam forms the reservoir of the volume 470 million m³. The concrete gravity dam of the height 81.8 m is situated in Podkarpackie voivodship. Reservoir has surface area of 22 km² at maximum water elevation 420 m a.s.l. The length of the dam is 646 m with 3 spillway bayes spans and two outlet works (Fig. 6). Initially the powerplant was designed as peaking power of the power 136 MW. During 2000–2003 power plant was modernized and has now 4 Francis units. Two are classic units and two reversible of the total power 200 MW. Energy volume of the upper reservoir amounts to 1.3 GWh.

The Lower Myczkowce Reservoir on the San River downstream of the Solina Dam has a capacity of 11 million m³. The reservoir is enclosed by a dam 386 m long and 17.5 m high. The dam is equipped with 2 Kaplan turbines with a total capacity of 8.3 MW.

Source: ZEW Niedzica

Fig. 7. The view of earthfill dam Czorsztyn-Niedzica with surface spillway and power plant

Dam and pumped storage power plant Czorsztyn-Niedzica on the Dunajec River

Dam Czorstyn-Niedzica, reservoir and power plant were commissioned in 1997 just before the arrival of flood wave on the

Source: WysokieNapiecie.pl

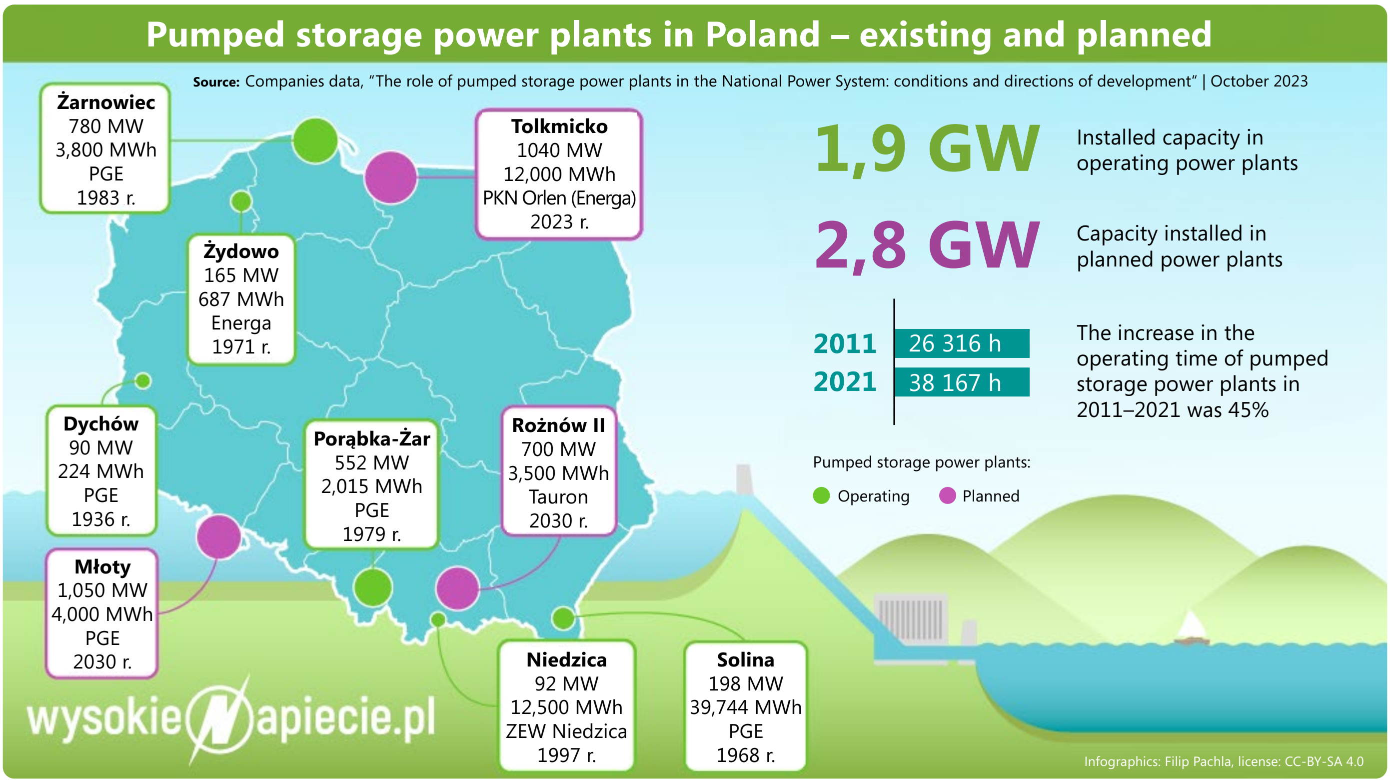

Fig. 8. Existing and designed pumped storage power plants in Poland

Dunajec River. The dam is in Małopolskie voivodship. The volume of the reservoir is 232 million m³. The normal water level in the reservoir is 529 m a.s.l. The dam is earth fill type with anti-seepage clay core and has the height 56 m and the length 404 m. Hydraulic power plant is equipped with two reversible Deriaz turbines of 92 MW power each in the turbine cycle.

Required power in the pomp cycle is 89 MW. The energy storage capacity of the reservoir is 1.0 GWh. The possible peaking and pumped storage operation is possible due to compensation reservoir Sromowce Wyżne of the volume 6.7 million m³. The current operation of the power station as a pumped storage power station is made possible by the Sromowce Wyżne compensation reservoir located downstream of below the dam. The compensation reservoir was originally constructed to compensate for the peak flow of the power station further downstream on the Dunajec River. The reservoir was built in 1972–94. The dam is 460 m long, 11 m high and has a 2 MW power plant equipped with 4 propeller turbines. The reservoir has an area of 0.95 km² and an equalization capacity of 5.4 million m³ (Fig.7).

Planned investments in ESP in Poland

In the case of pumped storage power plants, the power of the installed units is a very important factor, as this determines the possibility of rapid start of turbine operation at maximum level, as well as rapid pumped operation to fill the upper reservoir. The capacity of the upper reservoir determines the amount of stored energy, the use of which is very flexible, as the turbines can operate at high efficiency at partial load (turbine flow). The power of the future PSP depends on the capacity and parameters of the upper reservoir and the installed turbine power of the power plant. It also forms the basis for determining the energy capacity of the upper reservoir. Poland has meager water resources and very law its hydroenergy utilization. Polish technical hydroenergy potential is estimated at 13,700 GWh annually and its present use is 2,000 GWh, which establishes 15% of possibility. It is necessary remember that power installed in pumped storage power plant and in classic power plants are two very different aspects. The increase of the power potential in pumped storage power plants is closely connected with more often utilized and storing renewable energy. Construction of the classic hydraulic power plants is related with broad interpreted renewable water resources.

In the PSPs mentioned above, a total capacity of 1,765 MW is installed. Three large PSHs are expected to be commissioned in the near future. These are: pumped storage powerplant Młoty, which was started and stopped quite a long time ago, with a capacity of 1,050 MW, Tolkmicko PSH with an installed capacity of 1,040 MW, and Rożnów II PSH with a capacity of 700 MW. Besides this, Pilchowice PSH with a capacity of 612 MW, Sobel with a capacity of 1,000 MW and Niewistka PSH with a capacity of 1,000 MW are being projected (Fig. 8).

It is important to remember, that Poland has very modest water resources and very low hydropower utilisation of them. Poland's technical hydropower potential is estimated at about 13,700 GWh/year and at present we produce about 2,000 GWh which is only 15% of the technical hydropower potential. It is important to remember that installed capacity in PSHs and in classic hydropower plants are two different things. The increase in potential in PSP is closely linked to the increasing use of energy from RES and the storage of this energy. In contrast, the construction of classic hydropower plants is related to water resources management.

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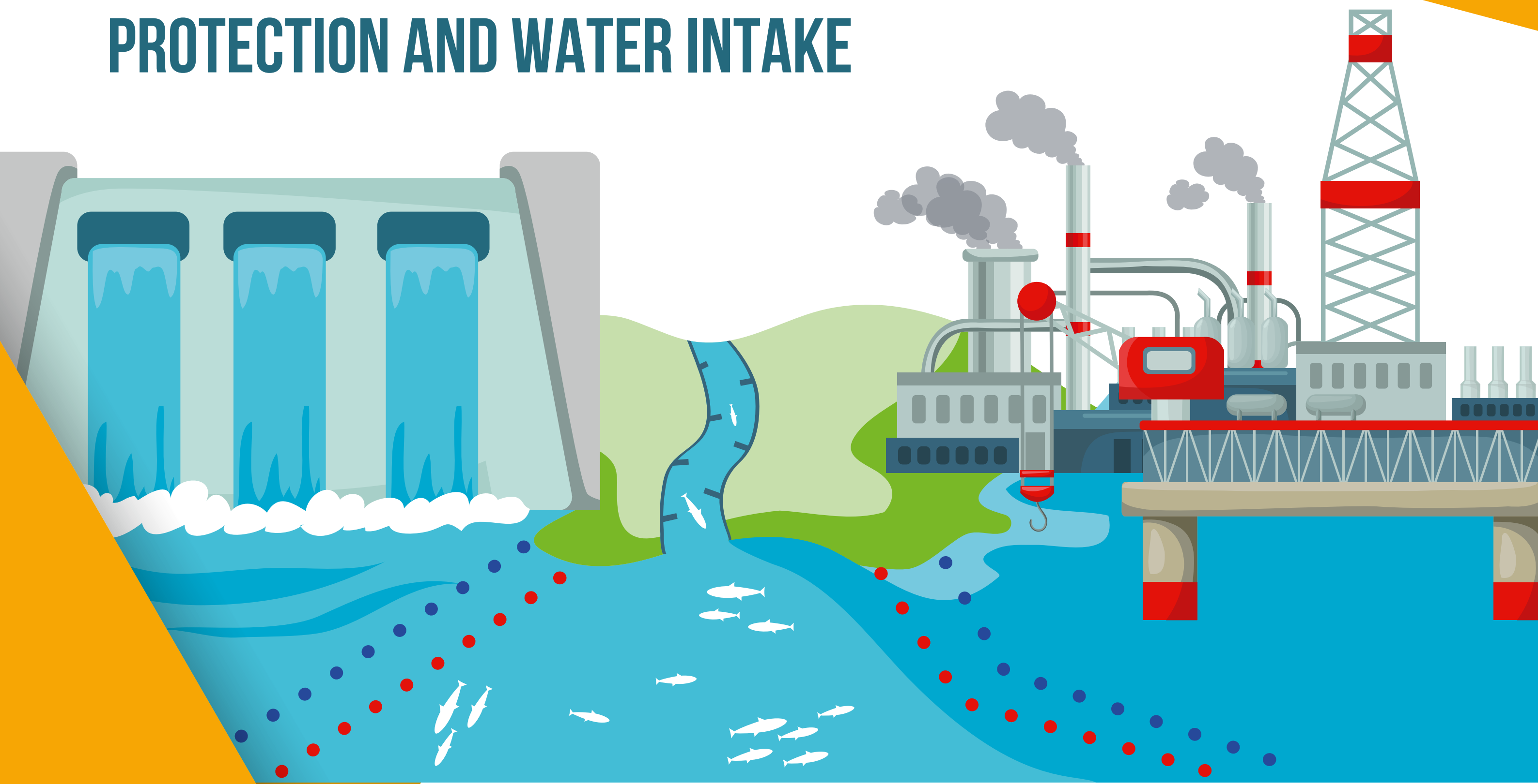

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Photo: Beaver on a creek in Sweden
Source: Getty Images

The beaver activity – a response to the water crisis

For a considerable period of time, water has been regarded as a "free" commodity, a commodity that is commonly available and unused, thereby denying it its status as a common and public good. Recent years have demonstrated that ongoing climate change is affecting water resources both qualitatively and quantitatively. The alteration in the seasonal pattern of precipitation and the persistent hydrological, agricultural, and hydrogeological drought have a detrimental effect on the quantitative status of water resources in Poland.

The answer to the water crisis is retention, both artificial and natural retention activities are key to increasing water resources. The selection of pursuits must be influenced by the specific characteristics of the geographical region and its requirements. In areas that are predominantly agricultural or forested, one of the activities that may be considered is assisting the activities of beavers. The beaver genus includes two species – the European beaver (Castor fiber) and the Canadian beaver (Castor canadensis). As a species, beavers are very territorial, and they build dams and lodges in the territories they occupy. Beaver families can occupy an area for about 10 to 15 years. This species habitat is closely related to streams or water reservoirs.

Beavers and small-scale retention

By creating ponds, it is possible to retain up to several thousand cubic meters of water. Furthermore, it is worth pointing out that the activity of beavers, which results in the increase in water, exhibits a certain stability, making it possible to refer to year-round water retention. The slow outflow of water from the beaver pond allows plants to use nutrients (phosphorus, nitrogen) and prevents eutrophication. It is generally estimated that in a beaver pond, water self-purification increases its effectiveness by up to 10 times. The activity of beavers is not just about the retention of the beaver pond itself, but also about the fact that, all around the beaver pond, the level of shallow groundwater is gradually rising, which counteracts the effects of agricultural drought and enhances the water and soil conditions of the area where beavers reside. Furthermore, numerous bends are formed around beaver ponds, which help to recreate marshy areas and wetlands. This effect also has a positive impact on the volume of retained water.[1]

Beavers and the environment

The habitat conditions created by beaver activity also affect the biodiversity of the area. The beaver pond provides a food base and appropriate conditions for the existence of fry. Salmonoids attract small predators, like the otter (Lutra lutra). Habitat conditions around the area inhabited by beavers are also favourable for entomofauna and herpetofauna. To summarize, the activity of beavers has the potential to effectively mitigate the effects of drought in the country and mitigate the effects of floods, rendering it a crucial component in the realm of mitigation and adaptation to climate change. Therefore, institutions responsible for water manage-

[1] Wpływ działalności bobrów na kształtowanie środowiska i gospodarowanie wodami na wybranych obszarach kraju, Praca zbiorowa, Warszawa, 2008

ment in Poland should strongly support it. The Ministry of Infrastructure and the Polish Waters State Water Management have reported that it is important to achieve retention of 15% of the average annual run-off for effective management of water resources. As mentioned above, one beaver pond, inhabited by one beaver family, can retain several thousand cubic meters of water. It is estimated that Poland is inhabited by approximately 50,000 beaver families. These numbers show the giant possibilities in terms of water retention.

Beavers vs. law

Despite the obvious benefits resulting from the activity of beavers, their activity is also a source of many conflicts. The construction of dams, grouse holes, and lodges can cause harm to agricultural and forest products, clog water-treatment facilities, and rip up flood-prone slopes. Sometimes, fallen trees and transmission lines get damaged by beavers or block local roads. Despite the above-mentioned benefits, it is crucial to be able to properly manage and counteract the conflicts described above. The legal situation of this species will be presented before I discuss ways to counteract conflicts. According to the letter of the law, the European beaver (Castor fiber) is covered by the provisions of Council Directive 92143/EEC of 21 May 1992 on the protection of natural habitats and wild fauna and for. The inclusion of it in Annex II imposes on the Member State the obligation to take appropriate measures to safeguard this species and its natural surroundings, thereby preventing the decline in the population's health. Considering the precarious state of this populace, Poland, in accordance with the provisions of the Directive, has devised a countermeasure, namely the inclusion of the domestic populace in Annex V, which permits the acquisition of individuals from the natural environment.

Furthermore, the legal status of the European beaver (Castor fiber) in our nation is regulated by 3 of the Regulations of the Minister of the Environment dated December 16, 2016 on the protection of animal species (Journal of Laws 2022.2380), which categorizes this species as a wild occurring animal under partial protection. Therefore, the restrictions outlined in the preceding paragraphs are applicable to this species. Moreover, the European beaver is also included in the list of partially protected species allowed for harvesting (§ 4 of the above-mentioned regulation) by shooting with a hunting weapon or catching in live traps: in the period from October 1 to March 15, harvesting requires a permit to the regional director for environmental protection or the General Director for Environmental Protection, as referred to in Art. 52 section 2 point 6, subject to the conditions referred to in Art. 56 section 5 of the Act of April 16, 2004 on nature protection (Journal of Laws of 2023, item 1336).

The beaver is not a game animal, as it should be noted. An important point to note is the fact that, according to Art 56a above, The Regional Director of Environmental Protection may regulate the population size of this species. The Regional Director of Environmental Protection has the authority to authorize, through an ordinance, for a specified period of time, not exceeding 5 years, through an act of local law, activities related to the European beaver that are subject to the prohibitions specified in Art 52 section 1 of the Act, within the area of its operation. In connection with this article, the following prohibitions may be waived in relation to wild animals of protected species:

- intentional killing,
- intentional mutilation or capture,
- transport,
- rearing or breeding, collection,
- acquisition, keeping, possession or preparation of specimens of species,
- destruction of habitats or refuges, which are their areas for breeding, rearing, resting, migrating or feeding,
- destroying, removing or damaging lodges, dams, wintering grounds or other shelters,
- intentionally moving them from places of regular residence to other places.

In the absence of alternative options, the order may be issued if the actions covered by it are not detrimental to the preservation of the wild populations of the species covered by it in an appropriate conservation condition. As a result, it functions as an instrument capable of regulating the number of beaver individuals. Furthermore, in accordance with Art 126 of the Act, the State Treasury is liable for damage caused by beavers. It is the responsibility of the regional director of environ-

Source: Wikimedia Commons, Phoenix-Five

Photo. A beaver dam on Twenty-Two Creek in Union Township near Traverse City, Michigan, USA

mental protection to inspect and assess the damage in question, as well as to determine the amount of compensation and its payment. In the case of a national park, it is the responsibility of the director. In regards to the compensation payment procedure, it is noteworthy that it must be executed in a manner that does not raise any doubts regarding the legitimacy and amount of the compensation paid.

Beavers and human activity

However, in the interest of all, it is necessary to develop strategies and procedures to prevent disputes in the realm of human activity – that of sagebrush activity. Researchers from Poland found that damage to technical, hydrotechnical and road infrastructure as a result of beaver activity is quite rare. The ongoing maintenance of hydrotechnical facilities is sufficient to counteract the activity of beavers. In the case of embankments, it is possible to use appropriate protection in the form of fences or metal meshes to prevent digging burrows. The highest number of conflicts, and consequently the need for minimizing measures, occur in the areas of forestry and agriculture. In the context of forest management, the activities of beavers result in the flooding of forest land, the direct destruction of tree stands, and the flooding of access roads, which may hinder the activities in forest areas. The key here is to designate areas that beavers could inhabit while excluding them from forest production. Such an action could be introduced into projects implemented by the National Forest Holding State Forests. However, most conflicts occur where beaver activity meets agricultural activity. Flooding of agricultural land, direct losses of crops, harvesting of beets, carrots, and corn, and flooding of pastures are some of the issues in this field.

Economic aspects of retention

It is important to emphasize that shaping retention by beavers is one of the ecosystem services. The average cost of water retention calculated for Poland is PLN 3.93 to PLN 4.50 per m³ per year.[2] Based on this basis, a system of subsidies could be proposed for farmers who devote part of their land to beaver activity. In the case of creating beaver ponds, the average depth is up to 0.3 m per ha, we get 300 m³ of retained water on the surface of the pond. Furthermore, water is retained in the soil profile, but calculations would require knowledge of the soil profile structure in order to estimate the percentage of retention potential. The length of the flood should be assumed for the entire year. With the above assumptions, the payment for the developed retention alone would range from PLN 1,179 to PLN 1,350/ha.

Considering the development of the beaver population in Poland, the greatest interest in this type of activities and subsidies should be in the following voivodeships:

- Greater Poland Voivodeship,
- Kuyavian-Pomeranian Voivodeship,
- Łódź Province,
- Lublin Province,
- Podlasie.

In addition to the aforementioned activities, it is imperative to implement information and educational initiatives to enhance public understanding of the necessity to engage in natural retention activities. This includes promoting awareness that a significant component of this area is supporting the activities of these diminutive mammals, who are often referred to as nature's hydrotechnicians.

The water crisis is becoming increasingly visible and tangible, and it is necessary to take immediate action to counteract the effects of drought and manage floods. It is crucial to shape small and micro-retention areas in forest and agricultural areas, so we should start making wider use of the ecosystem services provided by beavers in this area because they are our ally in this area.

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[2] Stelenga J. (red.), Rekomendacje zmian w programie rolnośrodowiskowym, Puławy, 2016


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